

## Remedial Investigation Report

**Former Philip Services Corporation Site  
Rock Hill, South Carolina**

**Prepared For: South Carolina Department of Health &  
Environmental Control**

September 2008

# *Remedial Investigation Report*

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# Executive Summary

This executive summary presents an overview of the background, results, and conclusions of the remedial investigation (RI) that was conducted at the former Philip Services Corporation (PSC) site in Rock Hill, South Carolina. The PSC Site is a former hazardous waste transportation, storage, and disposal facility. Operations began at the site in 1966 and continued until 2003. These operations included waste incineration from 1980 to 1995. The South Carolina Department of Health and Environmental Control assumed environmental management responsibilities for the site in December 2003, when the current owners went bankrupt.

The objectives of the RI were to:

- Characterize the soil and sediment associated with site-related activities, particularly in previously identified Solid Waste Management Units, Areas of Concern, and waste operations/storage areas where limited or no soil samples have previously been obtained.
- Assess surface soil risks for the undeveloped portion of the site east of Wildcat Creek.
- Identify potential sources of constituents in groundwater and determine the nature and extent of these sources.
- Identify and/or confirm potential migration pathways.
- Characterize the nature and extent of contaminants in groundwater.
- Assess risks to human health.
- Support the development of the Feasibility Study (FS).

Camp Dresser & McKee Inc. (CDM) completed several activities to support these objectives, including reviewing data collected in previous investigations, sampling various environmental media (e.g., soil, groundwater, and sediment), installing additional monitoring wells, performing remedial technology engineering evaluations, and assessing potential human health risks. The RI field work was conducted in three phases from May 2006 through December 2007. The phased approach allowed for focus data collection with each phase building on the previous phase and addressing remaining data gaps.

The results of the RI revealed that contaminant migration and fate characteristics are controlled by four dominant hydrogeologic features: saprolite, alluvium, partially weathered rock (PWR), and bedrock. The saprolite contains shallow groundwater. Contaminants present in the saprolite migrate to the alluvium, PWR, and bedrock features. The alluvium is more permeable than the saprolite and exerts a high degree of control over the site hydrogeology. Contaminants migrating to the alluvium are



likely diluted by a higher flux of groundwater through this zone before eventually discharging to Wildcat Creek. The configuration of the PWR at the site is highly variable, and groundwater will either migrate from this zone to the alluvium or bedrock. Groundwater in the bedrock is controlled by fractures, and groundwater from this zone migrates to either alluvium deposits or underneath Wildcat Creek.

The results of environmental media sampling during the RI revealed that several chemicals, predominantly volatile organic compounds (VOCs), were detected above regulatory screening criteria in both surface and subsurface soil. Detected concentrations above criteria are limited to four soil focus areas: 1) Warehouse (Drum Storage and Management) Area, 2) Incinerator / Drum Repackaging Area, 3) Solvent Ditch Area, and 4) South Drum Storage Area. The highest concentrations in soil were detected in the Incinerator Area. The presence of several VOCs above EPA Region 9 Soil Screening Levels (SSLs) indicates that ongoing sources of groundwater contamination may be present in these areas.

The groundwater sampling results from the RI were consistent with the soil sampling results. In general, groundwater concentrations were high in areas with high soil concentrations. Several monitoring wells on site, encompassing the warehouse to Wildcat Creek, contain concentrations above EPA Maximum Contaminant Levels. Similar to soil, four focus areas were identified for soil based on observed concentrations and potential source areas: 1) Incinerator / Drum Repackaging Area, 2) Solvent Ditch Area, 3) Burn Pits, and 4) Fuel Oil Area.

The human health risk assessment conducted for the RI indicated that site-related environmental contamination posing potential cancer risks and noncancer hazard are related to contaminated groundwater, surface soil, and subsurface soils. The pathways of principal concern are exposure to chlorinated VOCs in groundwater through drinking water ingestion, and inhalation of VOCs in indoor air originating from groundwater. The final chemicals of concern (COCs) in soil related to potential human exposure risks are primarily metals (thallium and vanadium), with chlorinated VOCs limited to subsurface soils in two hot spot locations (RISB-25 and RISB-64). However, 19 additional chemicals were identified as COCs for soil based on SSL exceedances. Sixteen VOCs along with manganese were identified as COCs in groundwater based on calculated risks as well as a comparison to drinking water standards.

# Section 1

## Introduction

This document presents the results of the Remedial Investigation (RI) at the former Philip Services Corporation (PSC) site in Rock Hill, South Carolina. The RI was performed in three phases (Phase I, Phase II, and Phase III) and field work was completed between May 2006 and September 2007. Data obtained from Phase I was incorporated in the planning of Phase II work. Following analysis of the data collected from Phase II, it was determined that Phase III activities were necessary to better assess the nature and extent of contaminants in groundwater.

### 1.1 Project Overview

The purpose of this RI Report is to document the results of the RI conducted at the former PSC Site. The RI was designed to further refine information regarding the nature and extent of contamination, and assess potential human health risks. The RI data will also support identification and evaluation of remedial alternatives during the Feasibility Study (FS).

Although the PSC site is not a National Priority List site under the U.S. Environmental Protection Agency's Superfund program, the RI Report has been prepared in observance of Superfund guidance (CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act). The RI has also been conducted in general accordance with the provisions of the *National Oil and Hazardous Substances Pollution Contingency Plan* (40 CFR 300).

The field work for Phase I was conducted during the weeks of May 29, 2006 and June 5, 2006. This work included completing site-wide investigations of the surface and subsurface soil, sediment, and groundwater. Additionally, the existing wells were inventoried. Based on the results of the Phase I Investigation, groundwater monitor well and additional subsurface soil locations were chosen for the Phase II Investigation.

The field work for Phase II was conducted between December 11, 2006 and March 5, 2007. The Phase II work included installing 20 groundwater monitor wells, completing 11 additional soil borings, conducting a site-wide groundwater sampling event, performing a multi-phase extraction pilot study, and performing an aquifer hydraulic assessment. The Phase II results revealed that data gaps remained for groundwater contamination extent. Thus, a Phase III investigation was conducted to address these data gaps.

The field work for Phase III was conducted between August 13, 2007 and September 20, 2007. The Phase III work included installing 11 groundwater monitoring wells and performing groundwater sampling on the 11 newly installed wells and select additional wells to confirm results from Phase II.

In addition to the data collected in the three phases of the RI, results from recent pre-RI investigations were used in the overall evaluation of site conditions.

## 1.2 RI Objectives

The objectives of the RI, as outlined in the RI/FS Work Plan (CDM, August 2006), were as follows:

- Characterize the soil and sediment associated with site-related activities, particularly in previously identified Solid Waste Management Units (SWMUs), Areas of Concern (AOCs), and waste operations/storage areas where limited or no soil samples have previously been obtained.
- Assess surface soil risks for the undeveloped portion of the site east of Wildcat Creek.
- Identify potential sources of constituents in groundwater and determine the nature and extent of these sources.
- Identify and/or confirm potential migration pathways.
- Characterize the nature and extent of contaminants in groundwater.
- Assess risks to human health.
- Support the development of the FS.

The data collected during the RI were designed to fill existing data gaps and satisfy these objectives. The results of the data collection efforts are presented in this RI Report.

## Section 2

# Project Background Summary

### 2.1 Site Description and Background

The PSC Site is a former hazardous waste transportation, storage, and disposal facility. In 1966, Quality Drum Company and Industrial Chemical Company began operations consisting of waste storage, treatment, and recycling. The facility received spent solvents from offsite facilities, stored the solvents on the site in drums and tanks, and recovered these solvents through distillation. Until 1980, wastes from the distillation process (still bottoms) were sent to a local landfill. In 1980, a hazardous waste incinerator was installed for still bottoms treatment.

In May 1983, Stablex Inc. acquired the facility. At that time, approximately 26,000 drums and 200,000 gallons of bulk liquid waste (stored in tanks) were present on the site. In 1986, ownership of the property was transferred to NUKEM, who changed the facility name to ThermalKEM in 1987. ThermalKEM operated as a hazardous waste incinerator and storage facility under RCRA interim status (EPA I.D. No. SCD 044 442 333). Phillip Services Corporation (PSC) took over operation and management of the facility in November 1995 and ceased operation of the incinerator one month later. The South Carolina Department of Health and Environmental Control (SCDHEC) assumed the environmental management responsibilities following the bankruptcy of PSC in December 2003.

Through the years of operation, the facility has sustained two large structural fires. The facility also experienced a subsurface diesel fuel release, with the quantity of fuel spilled estimated to be greater than 200,000 gallons. Based on several investigations and groundwater sampling, an extraction and treatment system was installed in 1988. Additional extraction components (groundwater extraction wells EW-2 and EW-3 and a fuel interceptor trench) were installed in the mid 1990s.

The incinerator was dismantled after it was shutdown, and a pit was excavated into soil beneath its footprint to remove contaminated soil. This work was performed prior to SCDHEC management of the site. In 2004, the excavated pit was backfilled and the incinerator building was demolished under the direction of SCDHEC. Upgrades to the treatment system were also completed in 2005.

**Figure 2-1** presents a current site location map. The site consists of approximately 44.5 acres of industrial property on the west side of Wildcat Creek and approximately 108 acres of undeveloped woodland on the east side of Wildcat Creek. Robertson Road borders the industrial portion of the property to the northeast, and the Norfolk Southern Railroad forms the northwestern boundary. Wildcat and Fishing Creeks border the industrial property on the southeast and southwest, respectively.

The site is immediately surrounded by undeveloped land and commercial/industrial properties. Osmose Wood Preserving Inc. is located directly across the railroad to the

northwest. Low-density residential properties and a high school are located in the vicinity of the site. Higher density residential areas are located to the southeast and northeast, towards the City of Rock Hill.

## 2.2 Previous Investigations and Remedial Activities

Several previous investigation and remedial activities have occurred at the PSC site. The timeline of events, as derived from Section 2.3 of the RCRA Facility Investigation Part 1 Report (PSC, August 1999), is shown in the following table. This table is not intended to be completely comprehensive of investigation and remedial activities, and CDM has been unable to confirm several of the activities and dates presented in the RCRA Facility Investigation Part 1 Report.

**Table 2-1**  
**Timeline of Investigations, Remedial Activities, and Other Events**  
Remedial Investigation Report  
PSC Site, Rock Hill, South Carolina

Date(s)	Activity
Prior to 1983	Six monitoring wells existed on site.
June 1983 to March 1984	Excess drum inventory was brought under permitted storage capacity, and contaminated surface soil was removed.
June 1983 to September 1984	Old tanks were cleaned out, and tanker trucks were removed and cleaned out.
1983	Burn pit soil was excavated.
	Groundwater monitoring was initiated.
	A soil investigation was conducted identifying soil type and general geotechnical conditions.
	Six additional monitoring wells were installed throughout the site.
	October The Solvent Ditch was removed and cleaned.
1984	A hydrogeologic study revealed "solvent-like odors" in borings slightly downgradient of the Solvent Ditch.
	Borings were completed as monitoring wells to assess groundwater quality in the vicinity of the Solvent Ditch.
	A quarterly groundwater quality monitoring program was initiated voluntarily.
1985	A geophysical investigation was conducted to search for buried materials at the site. The Burn Pits were identified and soil in this area was excavated.

Date(s)	Activity
1985 and 1986	Additional hydrogeologic investigations were performed to assess groundwater quality in the vicinity of the Solvent Ditch.
November 1986	Water identified in the Incinerator Building Sump during EPA's RCRA Facility Assessment was removed. The leak found to be the source of water was repaired.
1986 and 1987	Studies were conducted to design an extraction well (EW-1) to contain and remediate groundwater at the Solvent Ditch.
1988  July	Well BP-1A installed in the area of the former Burn Pits.
	Extraction well EW-1 was installed and connected along with production well PW-1 to the plant groundwater treatment system. Pump and treat remediation of groundwater began.
	RCRA Part B hazardous waste incinerator and storage permit SCD04444233 was issued but appealed by a local citizen's group.
	An aquifer performance test was conducted at extraction well EW-1.
June 1990	Diesel fuel was detected in piezometer P-2 during the routine measurement of water level elevations.
1991  February	An investigative study and remediation feasibility study was conducted for the diesel fuel area.
	The Preliminary RFI on the diesel fuel area was submitted to EPA.
1992  January  March  January and July	Pumping of production well PW-1 was discontinued because volatile organic compound (VOC) concentrations at MW-100 had decreased to below detection limits.
	An additional product delineation investigation was conducted in the diesel fuel area.
	A lineament study of regional fracture traces was conducted.
	ENSR conducted field investigations in support of the RFI Work Plan to be submitted in August 1992. Five saprolite wells and three bedrock wells were installed, including three well points in the bed of Wildcat Creek.
July 1993	Diesel fuel was detected in EW-1. The pumping rate was decreased to between 10 – 25 gallons per minute (gpm).
September and	Extraction wells EW-2 and EW-3 were installed.

Date(s)	Activity
October 1994	
August to October 1995	The diesel fuel interceptor trench was installed.
December 1995	Operation of the incinerator ceased and a revised Part B Permit Application was submitted.
February and March 1996	EW-2, EW-3, and the interceptor trench were connected to the groundwater treatment system. The trench sump pump was also connected to an oil/water separator unit.
April to June 2004	Additional investigations were conducted by CDM and SCDHEC involving groundwater sampling, surface water sampling, surface soil sampling, and a test pit investigation.
June 2004	Incinerator excavation pit was backfilled and the incinerator building was demolished.
September – October 2005	Upgrades were completed for the extraction and treatment system consisting of replacing equipment and adding instrumentation and automation.

Through the RCRA Part B Permit Corrective Action process at the PSC site, four SWMUs and seven AOCs were identified and included in the permit. These SWMUs and AOCs are graphically shown on **Figure 2-2**. The SWMUs and AOCs, as listed in the RFI Part 1 Report, and a brief description of the wastes managed/disposed in each area are presented below:

- **Incinerator Building Sump (SWMU 8)** – contained incinerator ash and water from the incinerator water seals. The incinerator was operated from 1981 to 1995.
- **Container Storage Area (SWMU 11)** – large drum storage area on ground surface containing drums of spent halogenated and non-halogenated solvents. This location was used for container storage from pre-1983 until 1995.
- **Truck Washing Station and Sump (SWMU 19)** – wastes managed included wash water, residue, and soil from trucks carrying spent halogenated and non-halogenated solvents. The truck washing station/sump was operated from 1981 until 1995.
- **Burn Pits (SWMU 41)** – previous disposal area of solvent distillation still bottoms by open pit burning. The burn pits were operated approximately between 1966 and the early 1970's. Impacted soil was excavated in this area in 1985 under supervision of SCDHEC.

- ***Solvent Ditch Area of Concern*** – spill and leakage from tank trucks and the tank farm migrated to this area via stormwater runoff. This ditch was operated from the 1960's until 1983. Soil excavation was performed to remove visibly impacted material in 1983.
- ***Fuel Oil Area of Concern*** – suspected diesel fuel leaks from underground piping associated with three underground storage tanks (USTs) and from diesel fuel delivery piping to the incinerator.
- ***Drum Repacking Area Fire Area of Concern*** – this building housed spent halogenated and non-halogenated solvents in lab pack form and drums of solids and sludges from spent solvents. The building was destroyed by fire in 1995 and rebuilt the same year.
- ***Blend Tank Overflow Area of Concern*** – tank farm where liquids containing spent halogenated and non-halogenated solvents were blended for incineration prior to 1995. After 1995, solvents were blended with diesel fuel in this area.
- ***Scrubber Containment Overflow Area of Concern*** – wastes managed at this location included caustic solutions of scrubber water with particulate matter from incineration.
- ***Boiler Explosion Area of Concern*** – the boiler was used as a backup steam supply for the scrubber and was replaced after it exploded in March 1991. No wastes were managed here but approximately 50 gallons of diesel fuel would have exploded with this boiler.
- ***Stormwater Outflows Areas of Concern*** – collection and outflow areas for stormwater runoff from the site and treatment, storage, and disposal areas.

These SWMUs and AOCs are described further in the RFI Part 1 Report. Figure 2-2 also identifies additional areas of concern for this RI/FS, including the Stablax Materials Area, other drum storage and management areas, and a stormwater pond. The Stablax Materials Area was identified by SCDHEC in historical photographs, and a geophysical survey conducted by SCDHEC indicated that there were subsurface anomalies in the area. While the Stablax Materials Area was planned for use as a disposal area, it is unknown whether any wastes were deposited there.

## 2.3 Environmental Setting

### 2.3.1 Topography and Drainage

The PSC site is located in the Piedmont Physiographic Province of South Carolina. This province is characterized by gently rolling hills and ridges intersected by stream and river valleys. Within the vicinity of the site, land surface elevations range from



about 650 feet east of the site down to about 480 feet on Fishing Creek south of the site (Figure 2-1). Elevations on the site average from about 510 feet to 530 feet.

Two surface water features are adjacent to the site. Fishing Creek flows from the northwest to form the south boundary of the site and continues to flow to the south downstream of the site. Wildcat Creek flows from the north to form the east boundary of the operations area of the former facility. Wildcat Creek flows into Fishing Creek along the south boundary of the site. Most surface drainage from the operations area of the former facility is directed to the east into Wildcat Creek through several stormwater outfalls. One stormwater outfall also directs surface runoff from the southwest corner of the operations area to Fishing Creek.

Although the topographic relief is relatively subtle in the site vicinity, topographic patterns do exist that may provide additional insight into subsurface conditions. **Figure 2-3** provides a visual aid for evaluating the topography and geomorphology of the site vicinity. It should be recognized that this figure has a vertical exaggeration of about 5 to 1. Vertical exaggeration is necessary to discern the topographic patterns. With regard to elevation and slope, three distinct patterns are discernable from the figure. The most striking pattern exists east of the site where elevations are the highest and surface slopes the steepest. This east geomorphic area is likely to be underlain by rock that has undergone less weathering than the other two geomorphic areas that have been eroded to lower elevations with low slopes. This is particularly true of the southwest geomorphic area, which has very subtle slopes and the lowest elevations in the site vicinity. This geomorphology indicates that the underlying rock is more weathered than the rock beneath the other two areas. The north geomorphic area has moderate elevations/slopes compared to the other two areas, and the underlying rock is likely moderately weathered.

Wildcat Creek follows the apparent contact between the north and east geomorphic areas. Prior to its confluence with Wildcat Creek, Fishing Creek follows the contact between the north and the southwest geomorphic areas. Below Wildcat Creek, Fishing Creek follows the contact between the east and southwest geomorphic areas. These geomorphic expressions and related surface water flow patterns have additional implications to the regional geology and hydrogeology, as discussed below.

### 2.3.2 Geology and Hydrogeology

The geology of the Piedmont Physiographic Province of South Carolina includes crystalline bedrock of metamorphic and igneous origin. The metamorphic rocks range from coarsely-crystalline, weather-resistant gneiss to easily weathered mica schist and the finer-grained form called phyllite. Igneous rock, referred to as gabbro, reportedly exists beneath the site. Gabbro is a crystalline rock that is dark in color and contains minerals that are moderately susceptible to weathering processes. It is probable that this gabbro has been subjected to some degree of metamorphism and may be more appropriately classified as a meta-gabbro. Although the mineral composition may not

be significantly altered by the regional metamorphism, it could have imparted structural changes in the rock such as development of regional fracture systems. If regional metamorphism has not affected the rock, stress-relief fractures are expected in this unaltered rock type.

The east geomorphic area is likely underlain by a rock more resistant to weathering than the rock beneath the site. This rock is also likely to be igneous in origin based on the uniformly radial drainage pattern that has developed in this area. This indicates that fractures having strong directional characteristics do not likely exist in the east area.

The regional nomenclature applied to aquifer systems in the Piedmont Province is to classify the system as the Piedmont Aquifer regardless of the depth zone. Groundwater in Piedmont Aquifer systems typically occurs in three zones of interest. In descending order these zones include the regolith zone, the transition zone between bedrock and the regolith, and the bedrock zone.

The regolith zone at the site consists primarily of saprolite, the unconsolidated weathering product of the underlying parent rock that retains the relic structure of the parent rock. The regolith zone also includes the recent stream alluvium deposits associated with Fishing Creek and Wildcat Creek. The regolith thickness at the site ranges from 15 feet to 35 feet. The saprolite and the alluvium are fully connected hydraulically and behave as a single groundwater zone. However, it is probable that the permeability of the alluvium (primarily sand with silt) is higher than the permeability of the saprolite (primarily silt with sand and clay size materials). The depth to groundwater in the regolith measured at the site ranges from 5 feet near the streams to 20 feet at the higher elevations.

Groundwater flow in the regolith zone is from areas of topographic highs to areas of topographic lows. Recharge to this zone occurs at all elevations from precipitation, and this recharge represents a driving force for groundwater flow. Where the land surface intersects the elevation of the saturated zone in the regolith (such as along streams), groundwater discharge occurs creating a groundwater migration pattern toward the nearest surface stream. Some quantity of groundwater in the regolith zone also migrates downward to recharge the transition zone and the bedrock zone.

The transition zone between the regolith and bedrock zones consists of partially weathered bedrock and primarily of rock fragments, boulder-size rocks, and fractured bedrock that is in full hydraulic connection with the overlying regolith zone. Wells typically cannot be installed through the transition zone using auger techniques, and rotary or sonic techniques are required.

Groundwater flow in the transition zone follows similar patterns to the regolith zone. However, because of groundwater flow through fractures, the flow path of least resistance may differ in this zone, and the permeability is typically much higher than the regolith zone. Some quantity of groundwater in the transition zone migrates

downward to recharge the bedrock zone. Lateral groundwater flow in the transition zone is toward discharge points such as streams. Groundwater in the transition zone may migrate in the downstream direction of stream flow before the vertical gradient effectively causes it to discharge.

Groundwater in the gabbro bedrock beneath the site occurs in the primary pore space of the rock and in fractures developed in the rock. The primary porosity of the gabbro is likely very low and not significant for groundwater migration. However, the primary porosity may contain site-related constituents that could be slowly released into fractures, resulting in low concentrations of site-related constituents in groundwater migrating through the fractures for an indeterminate period of time.

The bedrock may include fractures developed from historic deformation events. These types of fractures are usually directional in nature, and a primary direction of fracture orientation can be discerned along with an antecedent fracture direction that tends to be about 60° from the primary direction. These fractures can exist at great depths in the Piedmont, and production wells can be successful at depths of over 500 feet. Stress relief fractures may also be present. These fractures develop as the weight of overlying rock is removed by weathering and the rock expands creating a fracture. Stress relief fractures are horizontal more so than deformations fractures and are usually rare below a depth of 200 feet.

Groundwater migration in the bedrock rock follows the same general rules as the other two zones and migrates from topographic high areas of recharge to topographic low areas of discharge such as streams. However, features of a more regional scale, such as major drainage basin divides and rivers, rather than features of a site-specific scale, such as Wildcat Creek, may influence groundwater flow patterns in deep bedrock. Furthermore, the groundwater flow paths of least resistance in the bedrock zone are along fractures. Based on potential fracture directions, the regional groundwater migration in bedrock ranges from southeast to southwest.

## 2.4 Historical Aerial Photographs

CDM obtained historical aerial photographs which show different levels of activity at the site during 1979 (Figure 2-4), 1984 (Figure 2-5), and 1989 (Figure 2-6). All aerial photographs were obtained from the United States Geological Survey.

## Section 3

# Remedial Investigation Approach

This section summarizes the field investigation activities completed at the PSC site. The section is divided into three major subsections: Phase I, Phase II, and Phase III. CDM prepared several documents to guide the RI and refine the approach, including:

- PSC Remedial Investigation/Feasibility Study (RI/FS) Work Plan (Work Plan) – CDM, May 2006
- Field Sampling Plan (FSP) - CDM, May 2006
- Quality Assurance Project Plan (QAPP) - CDM, Revised December 2006
- Phase I Technical Memorandum and Phase II Work Plan (Phase I Report) - CDM, October 2006
- Phase II Sampling Results and Hydrogeologic Findings – Interim Report (Phase II Report) - CDM, May 2007

The results of the RI are included in Section 4 (Summary of Findings). A summary of all soil and permanent monitor well sample locations, including wells installed prior to the Remedial Investigation, is provided in **Figure 3-1**.

### 3.1 Phase I Activities

This subsection describes the Phase I field activities, which were conducted in general accordance with the approach and procedures prescribed in the approved Work Plan and FSP. Some deviations occurred based on field observations, access conditions, and SCDHEC recommendations. These deviations are discussed further in Sections 3.1.2 and 3.2.2.

Specifically, CDM conducted the following activities during Phase I:

- Surface/subsurface soil sampling at 52 onsite locations (RISB-1 through -52) and two offsite background locations (RI-BCK1 and RI-BCK2).
- Surface soil sampling at 10 locations (RISS-1 through -10) on the undeveloped property east of the industrial facility, across Wildcat Creek.
- Sediment sampling at seven locations (RISD-1 through -5, RISD-WCBK, and RISD-FCBK) in Wildcat Creek and Fishing Creek.
- Sediment sampling at two onsite locations, one in a stormwater catch basin (RICB-3) and one inside the warehouse building (RI-WASTE).
- Groundwater sampling at four onsite locations (RITW-12, -28, -34, and -38)

- Well inventorying of existing groundwater monitor wells using available documentation.

Phase I did not include surface water sampling because an extensive surface water investigation was previously completed in 2004 by CDM and SCDHEC and revealed minimal surface water impacts. That investigation included installing vapor diffusion modules in Fishing and Wildcat Creeks and performing onsite screening using a portable gas chromatograph. The investigation also included collecting surface water samples for offsite laboratory analyses. Limited impacts were observed in the onsite screening and no organics were detected in the laboratory surface water samples. Additional details can be found in the *Summary Report – Initial Site Investigation* (CDM, October 2004).

Summary Phase I location maps are provided as **Figure 3-2** and **Figure 3-3** for activities on the west and east side of Wildcat Creek, respectively. A sample summary table is presented as **Table 3-1**. Additional Phase I activity details are provided in the following subsections.

### 3.1.1 Soil Sampling

Phase I soil sampling consisted of three sampling activities: onsite surface and subsurface soil sampling, surface soil sampling across Wildcat Creek, and background surface and subsurface soil sampling.

#### Onsite Soil Sampling

Surface and/or subsurface soil samples were collected from 52 onsite locations using direct push technology, as shown on Figure 3-2. Samples were collected in each boring from the surface (0-1 feet) and at 2-foot intervals thereafter up to the groundwater table (or refusal). Soil lithology was recorded for each of the subsurface locations, and the boring logs are presented in **Appendix A**.

Each of the collected samples was screened onsite shortly after collection using Color-Tec methods as an early indication of volatile chlorinated ethenes. Details regarding the Color-Tec procedure are available in the Field Sampling Plan (CDM, May 2006). Phase I Color-Tec screening data are presented in **Appendix D, Table D-4**. This table includes photoionization detector (PID) readings for each sample and a correlation of Color-Tec data to laboratory results. Color-Tec and PID results were used for screening purposes only. They were not included in the human health risk assessment and will not be used for remedial action evaluations.

In general, each surface soil sample was sent to Analytical Services Inc. (ASI) for analysis of EPA's Target Compound List (TCL) of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs), and EPA's Target Analyte List (TAL) for metals. One subsurface soil sample from each boring was also submitted to the laboratory for the same analyses. The subsurface sample was generally selected based on the interval that showed the highest Color-Tec or PID result. Samples in the

vicinity of the former incinerator and drum storage areas were also analyzed for polychlorinated biphenyls (PCBs). Table 3-1 shows the complete laboratory sample summary.

Five of the originally planned boring locations were modified, and another eight locations were added. These changes were based on the Color-Tec screening results, access conditions, and/or SCDHEC guidance. The changes were designed to better satisfy the RI/FS objectives. A summary of changes from the original approach is shown on Table 3-2.

Other deviations from the work plan included the following:

- Subsurface laboratory split samples were collected from 4-foot intervals instead of 2-foot intervals for logistical reasons.
- Because eight sample locations were added, SCDHEC attempted to minimize the additional number of laboratory samples by using the onsite screening data. The sample summary provided in Table 3-1 shows what samples and analyses were run for each boring location, and Table 3-2 summarizes the changes that were made.

### **Sampling across Wildcat Creek**

Ten surface soil samples were collected across Wildcat Creek in the undeveloped and wooded area of the property, as shown on Figure 3-3. This quantity of samples (1 for every ~10 acres) was intended to provide sufficient data for statistical analysis, if required. It was also intended to allow representation of the entire undeveloped area. There were no deviations from the work plan associated with surface soil sampling across the creek. Surface soil samples were sent to ASI for analysis of TCL SVOCs and TAL Metals.

### **Background Sampling**

In addition to the onsite borings, two background soil samples were obtained for surface (0-1 foot) and subsurface (3-4 feet) with a hand auger within a 1-mile radius of the site. RISB-BK1 was collected approximately 1,000 feet northwest of the site, north of Robertson Road. RISB-BK2 was collected south of South Pointe High School, approximately 0.5 miles from the site. The approximate locations of the background samples are shown in Figure 3-3. Background samples were sent to ASI for analysis of TCL VOCs, SVOCs, and TAL Metals.

### **3.1.2 Groundwater Sampling**

During Phase I, the Geoprobe® encountered refusal prior to reaching the water table in most of the borings. Therefore, groundwater samples could not be obtained in all boreholes as originally planned, nor could they be obtained from multiple depths.

Temporary wells were installed and allowed to recharge at nine locations (RITW-11, -12, -13, -15, -21, -25, -28, -34, and -38) where the water table was reached. Of the temporary well locations, four (RITW-12, -28, -34, and -38, as shown on Figure 3-2) provided sufficient recharge for sample collection. Samples were collected from each of these locations and sent to ASI for TCL VOC analyses. An additional sample for Color-Tec analysis was obtained from RITW-15. However, this location did not yield enough groundwater for VOC analysis.

Each temporary well was completed as a 1-inch well with a 10-foot screen. Groundwater was sampled from the wells between 24 and 48 hours following installation using low-flow sampling methods with a peristaltic pump. All temporary wells were abandoned by removing the PVC riser/screen and grouting the hole with a tremie pipe.

### 3.1.3 Sediment Sampling

Sediment sampling was conducted at seven locations along Wildcat Creek and Fishing Creek, as shown in Figure 3-2. Two of these locations (RISD-WCBKG and RISD-FCBKG) represent background conditions upstream of the site, one for each creek. The remaining locations were intended to be immediately downgradient of the scour areas for Outflows 1, 2, 3, and 4 and for the former burn pits.

A sediment sample was collected from only one stormwater catch basin (RICB-3) as sediment was not present in the remaining catch basins identified in the work plan. An additional sediment sample (RI-WASTE) was collected inside the warehouse building at SCDHEC's request after a pool of water was discovered near the former drum conveying area.

All sediment samples were collected using stainless steel bowls and spoons. The stream sediment samples were collected immediately downstream of each outflow location. Background sample RISD-WCBKG was collected approximately 50 feet upstream of Robertson Rd, and background sample RISD-FCBKG was collected upstream of Vernsdale Rd (about 50 feet north of the railroad tracks).

Sediment samples were sent to ASI for analysis of TCL VOCs, SVOCs, and TAL Metals.

### 3.1.4 Monitor Well Inventory

CDM conducted a monitor well inventory of the existing wells at the PSC site. This task consisted of reviewing available boring logs, construction details, and analytical data for each well. The objectives of this task were to develop a better understanding of well construction and usability and to determine a groundwater sampling scope for Phase II.

## 3.2 Phase II Activities

Phase II included supplemental soil sampling, monitor well installation, and monitor well sampling to support the RI objectives. Phase II included the following activities:

- Focused soil sampling to further characterize and bound the extent of constituents (horizontal and vertical) and to isolate potential source areas.
- Installing 13 shallow (Regolith or PWR) and 4 bedrock monitoring wells, 3 piezometers, and 5 staff gages to further refine the extent of contaminants in groundwater and to support FS evaluations.
- Conducting site-wide groundwater sampling to locate groundwater source areas and migration pathways.
- Collecting engineering data to support the FS.

These activities were described and completed in general accordance with the Phase I Report. The FSP was also used as a guide for some of the procedures followed during Phase II.

### 3.2.1 Additional Soil Sampling

Soil borings were completed at 11 locations (RISB-56 through -59 and RISB-61 through -67), as shown in **Figure 3-4**. Samples were collected from each of these locations at various depths and submitted to ASI for analysis. The sampling depths and associated analysis parameters are summarized in **Table 3-3**.

Soil samples were also collected at eight additional monitor well installation locations (RIMW-1, -5 through 8, -13, -19, and RIPZ-3), as shown on **Figure 3-4**. The sampling depths and analysis parameters are summarized in **Table 3-3**.

Boring logs for the additional soil samples are located in **Appendix A**.

### 3.2.2 Well Installation

Seventeen groundwater wells (RIMW-1, RIMW-3 through -16, and RIMW-18 and -19) and three piezometers (RIPZ-1 through -3) were installed, as shown on **Figure 3-4**. Of these 20 well/piezometer locations, 4 were completed in the saprolite horizon, 11 were completed in the partially weathered rock (PWR) horizon, and 5 were completed into bedrock. Geologic logs and well construction details for all of the wells installed in Phase II are located in **Appendix B**.

The bedrock wells were installed into competent bedrock using air-drilling techniques. The wells were set as specified in the Phase I Technical Memorandum and Phase II Work Plan (CDM, October 2006) for bedrock wells, and are conventional monitor wells (2"-PVC casing/screen, silica sand pack, bentonite seal, and cement



grout annular fill). Piezometer well RIPZ-2 was installed the same as the conventional monitor wells except 1"-PVC casing/screen was used instead of 2" PVC.

The saprolite and PWR wells were installed using auger or air rotary techniques. These wells were set as specified in the Phase I Technical Memorandum and Phase II Work Plan (CDM, October 2006) for shallow wells, and are conventional monitor wells (2"-PVC casing/screen, silica sand pack, bentonite seal, and cement grout annular fill). Piezometer well RIPZ-1 was installed the same as the conventional monitor wells except 1"-PVC casing/screen was used instead of 2" PVC.

In addition to standard installation procedures; rock coring, packer testing, and geophysical logging were performed on select wells to establish depth intervals for well installation.

Rock coring was performed for wells RIMW-18 and RIMW-19. These cores were evaluated to determine fracture zones and orientations to assist in the decision process when setting screen intervals for bedrock wells. Photos of rock cores are provided in **Appendix C**.

Packer tests were used when installing bedrock wells to determine the most appropriate interval to set screens. Groundwater samples were collected using packer tests for RIMW-18 at depth intervals of 44-56 ft bls and 56-68 ft bls and for RIMW-19 at depth intervals of 63-75 ft bls and 76-88 ft bls. Split samples were collected for each interval: one split was analyzed onsite for chlorinated ethenes using the Color-Tec method and the other split was sent to ASI for laboratory analysis of VOCs by EPA Method 8260B.

The results from the Color-Tec analysis were used to determine if additional depth intervals needed to be sampled. The laboratory data were used to confirm the Color-Tec data before setting the wells. Laboratory results from the packer tests are provided in **Table 3-4**. Color-Tec data for these two wells are presented in **Appendix D**, **Table D-4**.

Geophysical logging services were provided by Dr. James Ursic of the Environmental Protection Agency (EPA). A summary of the geophysical tools used and analysis conducted is presented in **Appendix C**. The **Appendix C** report includes geophysical logs and photographs of rock cores.

### **3.2.3 Site-Wide Groundwater Sampling**

Two weeks following well installation, a site-wide groundwater monitoring event was conducted. This event included sampling the newly installed wells as well as several existing wells, as identified on **Table 3-3**. This table also includes the analysis parameters for each sampled well. All samples were sent to ASI for analysis as shown in **Table 3-3**. In addition to sampling, site-wide water level measurements were recorded.

### 3.2.4 Engineering Data Collection

Additional data were collected during Phase II to support remedial technology engineering evaluations for the FS. Activities performed included the following:

- Aquifer Hydraulics Tests
- Dual Phase Extraction Pilot Tests
- Biochemical and Geochemical Data Collection

#### 3.2.4.1 Aquifer Hydraulics Tests

CDM performed several tests to assist in the evaluation of aquifer hydraulics of the bedrock and regolith hydrogeologic zones. Prior to the testing, CDM collected site-wide groundwater levels for comparison purposes.

To allow the aquifer to approach equilibrium without any extraction well operation influences, the extraction wells and trench pumps were stopped. The aquifer was allowed to stabilize for two weeks while collecting water levels from 14 locations as shown on **Figure 3-5** (eight manually and five using automated water level recorders). Following two weeks of aquifer stabilization, site-wide water levels were collected again.

Once all the data were obtained from the aquifer equilibration period, aquifer performance tests were performed on wells EW-2 and EW-3. These tests consisted of a six-hour step test. Pumping rates used were approximately 2 gallons per minute (gpm), 3 gpm, and 3.5 gpm for both EW-2 and EW-3. The work plan indicated that four steps would be performed, but only three were performed because the maximum yield was reached during the third step, making the third step the maximum pumping rate step. The step tests were followed by a 72-hour aquifer constant rate performance test (APT). The pumping rates for the APT tests were 2.7 gpm and 3 gpm for EW-2 and EW-3, respectively. **Figure 3-5** shows the locations of wells EW-2 and EW-3 and also shows the location of observation wells used to monitor water levels during the tests.

#### 3.2.4.2 Multi-Phase Extraction Tests

Multi-phase extraction (MPE) tests were performed by Kemron Environmental Services, Inc. to evaluate potential remediation technologies for source area chlorinated VOCs and the fuel oil area. The system extracts both subsurface vapor and liquid from a monitoring or recovery well through the application of varying levels of vacuum pressure. To control the liquid level and prevent groundwater mounding, a drop tube is inserted in the well to the static water level depth. The vacuum and airflow are conveyed through the drop tube. As the water table begins to rise from the vacuum, both free product and groundwater are extracted through the drop tube as the drop tube maintains the water level.

The first MPE test was conducted in the solvent ditch area as shown in **Figure 3-6**, and RIMW-8 was used as the extraction well. Surrounding wells were used to monitor pressure changes at varying distances from RIMW-8: MW-110A (56 feet), P-1 (105 feet), RIMW-4 (119 feet), RIMW-5 (112 feet), and OB-8A (50 feet). The pilot study was conducted at two induced vacuum pressures (6.5 in Hg and 17 in Hg), and measurements were taken until pressure readings stabilized during each test.

The second MPE test was conducted in the fuel oil area as shown in **Figure 3-6**, and PW-2A was used as the extraction well. The following surrounding wells were used to monitor pressure changes at varying distances from PW-2A: P-2 (20 ft), OB-900 (20 ft), OB-21 (6 ft), OB-22 (11 ft), and OB-23 (20 ft). The pilot study was conducted at induced vacuum pressures of 8 in Hg and 16.5 in Hg, and measurements were taken until subsurface conditions stabilized for each induced pressure. Following the first two induced pressure extractions, the vacuum pressure was increased to 23 in Hg to maximize fluid recovery.

#### **3.2.4.3 Biochemical and Geochemical Data Collection**

The biochemical and geochemical data were collected to evaluate in situ remedial technologies for source control and groundwater remediation. Bio- and geochemical data were collected from 12 wells as shown in Table 3-3 during the Phase II groundwater sampling event. Results are presented in Section 4.

### **3.3 Phase III Activities**

Phase III activities were conducted based on additional data gaps discovered during analysis of the groundwater data following Phase II activities. The Phase III approach was outlined in the Phase II Sampling Results and Hydrogeologic Findings Interim Report (CDM, May 2007), and the work performed during Phase III included the following activities:

- Installing 11 additional wells and abandoning 11 wells.
- Geophysical logging by EPA on selected wells during construction.
- Conducting groundwater sampling on the newly installed wells and selected existing wells to confirm findings in Phase II.

Correspondence with SCDHEC prior to Phase III activities resulted in some changes to the scope of work originally outlined in the Phase II Interim Report. These changes included:

- Recording soil lithology during well construction
- Adding one saprolite monitor well (RIMW-24)

- Installing diffusion bag samplers in RIMW-15 and collecting samples from these diffusion bags for onsite screening and laboratory analysis
- Adding three existing wells (RIMW-15, MW-121B, and MW-122B) to the groundwater sampling event
- Revising the well abandonment plan to cover the following 11 wells: MW-123B, MW-116, MW-117, OB-12, OB-13, OB-21, OB-23, OB-900, OB-901, OB-902, and PW-2A. Although PW-1 and RIMW-15 were initially selected to be abandoned by SCDHEC, they were not abandoned based on SCDHEC direction in the field. PW-1 was not abandoned because a pump was encountered in the well that could not be readily removed and RIMW-15 was not abandoned because diffusion sample results indicated that the well is not screened in multiple zones as previously suspected.

### 3.3.1 Well Installation and Abandonment

Eight bedrock groundwater monitor wells (RIMW-20, -21, -22, -23, -25, -26, -28, and -29) and three saprolite/PWR monitor wells (RIMW-24, -27, and -30) were installed to further refine the extent of contaminants in groundwater and to support FS evaluations. These monitor well locations are shown on **Figure 3-7**.

The bedrock wells were installed into competent bedrock using sonic drilling techniques. These wells were set as specified in the Phase II Work Plan for bedrock wells, and are conventional monitor wells (2"-PVC casing/screen, silica sand pack, bentonite seal, and cement grout annular fill).

Although monitor well RIMW-27 was intended to be installed as a bedrock well, it was not screened in bedrock. After setting steel casing into competent rock, it became apparent that the casing was set in "false rock". The casing was likely set in a rock ledge or boulder. At the direction of SCDHEC, the well was installed at the total depth achieved in this location.

The saprolite wells (RIMW-24 and RIMW-30) were installed to the top of PWR using sonic drilling techniques. These wells were set as specified in the Phase II Work Plan for shallow wells, and are conventional monitor wells (2"-PVC casing/screen, silica sand pack, bentonite seal, and cement grout annular fill).

Boring logs for these wells are provided in Appendix A, and construction well diagrams are provided in Appendix B.

Eleven well locations were also abandoned as shown in Figure 3-7. These locations were abandoned for the following reasons:

- Multiple Zone Wells – select wells with sand pack interval that connects the bedrock zone with a higher hydrogeologic zone (PWR, saprolite, etc.) or are screened across the bedrock zone and a higher hydrogeologic zone were

abandoned. This is because the data (e.g., water quality and water levels) from such wells are not likely representative of any single hydrogeologic zone.

- Redundancy – select wells that are screened in the same hydrogeologic zone as another well, are screened within five vertical feet of that well, and are in relative proximity to the well are considered to be redundant. These wells were also recommended for abandonment. When comparing wells, the well with the least amount of information available (e.g., boring logs, well construction details, etc.) was abandoned over wells with more complete information.
- Insufficient data – select wells that do not have sufficient information to know if they are screened in multiple hydrogeologic zones were abandoned.

At SCDHEC's request, CDM performed diffusion sampling in four equal intervals (70-77.5 ft bls, 77.5-85 ft bls, 85-92.5 ft bls, and 92.5-100 ft bls) of the 30-foot screen of RIMW-15. Each diffusion sampler was screened on site using Color-Tec methods. Two diffusion samples were selected for offsite laboratory analysis. The results of this analysis are shown in **Table 3-5**. Color-Tec data for the diffusion samplers are presented in Appendix D, Table D-4.

### 3.3.2 Groundwater Sampling

Two weeks following well installation, groundwater sampling was conducted for the wells identified in **Table 3-6**. This event included sampling the newly installed wells as well as three existing wells (RIMW-15, MW-121B, and MW-122B). This table also includes the analysis parameters for each sampled well. All samples were sent to ASI for analysis of TCL VOCs. In addition to sampling, site-wide water level measurements were recorded.

## Section 4

# Remedial Investigation Results

This section summarizes the results of the Remedial Investigation (RI). The RI was completed in three phases and included a hydrogeologic evaluation; soil (surface and subsurface), sediment, and groundwater investigations; hydraulic testing; MPE testing; and biochemical and geochemical data collection.

The RI design and investigation procedures, Phase I results, and partial Phase II results were presented in the Work Plan, Phase I Report, and the Phase II Report.

The summary of findings presented below includes a comparison of detections against regulatory criteria. The regulatory criteria, including EPA Region 9 Preliminary Remediation Goals (PRGs), EPA Region 9 Soil Screening Levels (SSLs), EPA Region 4 Ecological Screening Values (ESVs), and EPA Maximum Contaminant Levels (MCLs), are presented in **Table 4-1**.

The tables and figures in the following sections show the detected compounds only. Summary tables of all the laboratory results are presented in **Appendix D**. The complete laboratory reports for the RI data are included on the enclosed CD-ROM. Hard copy laboratory reports with raw data are on file at CDM.

### 4.1 Site-Specific Hydrogeology

#### 4.1.1 Geology

The site-specific hydrogeology was found to be consistent with expectations developed during work plan preparation. In descending order, three hydrogeologic zones were identified that include the regolith zone (shallow), the transition zone between bedrock and the regolith (intermediate), and the bedrock zone (deep).

The regolith zone at the site consists of two primary types of unconsolidated formation materials. Saprolite is the dominant type and is the unconsolidated weathering product of the underlying parent rock that retains the relic structure of the parent rock. The saprolite consisted of a wide range of grain sizes ranging from clay to silt to sand. Generally, the grain size is smaller near land surface and increases in size with depth down to the transition zone where rock fragments (gravel-sized grains) are common. The saprolite thickness is typically about 20 to 30 feet.

The regolith zone also includes the recent stream alluvium deposits associated with Fishing Creek and Wildcat Creek. **Figure 4-1** shows the estimated area underlain by alluvial deposits. Based on the recent borings, the alluvium consists primarily of sand with sand and gravel deposits found in closer proximity to Wildcat Creek. The alluvium typically occurs to a depth of about 20 feet and was observed to be the thickest at location RIMW-23, where medium- to coarse-grained sand and gravel was encountered to a depth of almost 35 feet.

The saprolite and the alluvium are fully connected hydraulically and behave as a single groundwater zone under water table conditions. Based on the geologic descriptions, the permeability of the alluvium is much higher than the permeability of the saprolite. The depth to groundwater in the regolith measured at the site ranges from 5 feet near the streams to over 20 feet at the higher elevations. In the west portion of the site, the water table may be deeper than the regolith zone, and the water table is located in the transition zone.

The transition zone between the regolith and bedrock zones consists of partially weathered bedrock and primarily of rock fragments, boulder-size rocks, and fractured bedrock that is in full hydraulic connection with the overlying regolith zone. The observed transition zone consisting of partially weathered rock (PWR) typically ranged from about 5 feet to about 25 feet. One exception in the PWR thickness was discovered at the location of RIMW-22 where the PWR was found to be about 85 feet thick.

Bedrock samples were obtained from the bedrock formation during the RI. The rock types encountered primarily included diorite, granodiorite, gabbro, norite, and diabase. Granodiorite and diorite were the most frequently encountered rock types. The mineral assemblages associated with these rock types include feldspar, hornblende, biotite, and chlorite. These rocks were medium to coarsely crystalline and tended to weather to friable PWR and sand-sized particles. The gabbro mineralogy primarily included pyroxene, hornblende, and chlorite. Diabase intrusions were also observed in the gabbro that demonstrated contact metamorphism as feldspar deposits.

The primary rock type observed at the northern portion of the PSC site was norite, which contains mostly plagioclase with some pyroxene. In the central and southern portions of the site, the feldspar content decreases, the pyroxene content increases, and the rock type becomes gabbro. The rock type on the western portion of the site has enough pyroxene that it could be considered a pyroxenite.

Other geologic observations included the presence of a diabase dike and minerals indicative of weathering of feldspars such as laumontite, chlorite, and epidote within fracture zones. Iron staining was also observed in selected fracture zones indicating that water had been present within the fracture zone. In a few locations, siderite and/or pyrite was observed in fracture zones. The foundational fracturing of the rock appeared to be the result of the intrusive activities, which created steeply dipping stress fractures trending northwest/southeast and northeast/southwest. Additional fracturing occurred as the result of the intrusion of two diabase dikes (elevations 430-420 ft and 388 ft), which were noted in three of the bedrock wells (RIMW-21, RIMW-22, and RIMW-26).

The effects of the fracturing were enhanced in portions of the site where elevated feldspar content was observed. The fracturing increased permeability, allowing water

to move within the fractured zones. Where the fracturing occurred within zones containing higher feldspar content, the enhanced permeability in combination with the susceptibility of feldspars to weathering allowed significant enhancement of the fracture zones and alteration of the feldspars to laumontite, epidote, and chlorite. Chemical alteration also occurred as the intrusive diabase dike reacted with the norite parent rock. From a depth of approximately five feet below the diabase dike and greater, the degree of fracturing and alteration is much less significant.

The highest degree of weathering/fracturing and the highest percentage of feldspar were observed at RIMW-20, 21, and 22, which are also the locations at the site where the depth to bedrock was significantly greater and where the diabase dikes were observed. Depth to bedrock at RIMW-26 was similar to RIMW-21; a diabase dike was also noted in RIMW-26. A zone of high fracturing and gravel was observed in the central portion of the site at elevations 470-460 ft at wells RIMW-25, RIMW-27, RIMW-28, and RIMW-29. This zone of gravel/relict fracturing may also be present in RIMW-22, RIMW-26 and RIMW-27, which contained PWR at elevation 470-460 ft. Another zone of gravel and high fracturing was observed at elevation 420-410 ft in the northern part of the site at RIMW-20, RIMW-21, and RIMW-22.

#### 4.1.2 Hydrogeology

Potentiometric surface maps were developed for the regolith (saprolite, alluvium, and PWR) and bedrock hydrogeologic zones from data collected in September 2007. The regolith/PWR potentiometric surface is shown on Figure 4-1, and the bedrock potentiometric surface is shown on Figure 4-2. The associated groundwater elevations are also summarized in Table 4-2. Calculated vertical gradients for select well pairs are presented in Table 4-3.

The regolith/PWR groundwater elevations decrease east-southeast toward Wildcat Creek. The hydraulic gradient is steeper in the west portion of the site that is underlain by saprolite and decreases in the vicinity of the creek where the regolith consists of alluvium. This difference in hydraulic gradient is believed to be associated with the alluvium being more transmissive than the saprolite. Regolith/PWR groundwater flows from the saprolite into the alluvium and then into Wildcat Creek. However, it is possible for the regolith/PWR groundwater to flow beneath Wildcat Creek in the alluvium for some distance downstream before effectively discharging into the active stream channel.

Bedrock groundwater elevations also generally decrease east-southeast towards the creek. However, in the area surrounding Wildcat Creek where stream alluvium is present, the groundwater flow pattern appears to be controlled more so by the alluvial valley rather than the current location of the stream channel. This actually is not very surprising because the bedrock groundwater discharge is more efficient where the alluvial valley is the deepest and the alluvium is most permeable. This area is expressed on the potentiometric surface map as a trough formed by the 507-foot contour.



### 4.1.3 Cross Sections

CDM has prepared hydrogeologic cross sections based on data obtained during the RI and previously existing data. Boring logs and well construction logs were recorded during the RI and are presented in Appendix A and B, respectively. Five cross sections were prepared, and the locations are shown in **Figure 4-3**. These cross sections were developed to correlate the hydrogeologic zones (shallow – saprolite, intermediate – PWR, and deep – bedrock). **Table 4-4** presents a well summary for all pre-RI and RI wells on site.

Cross Section 1 (CS1) was used to evaluate the north-central portion of the groundwater plume and to evaluate the relationship with extraction well EW-2 and surrounding wells. CS2 was used to evaluate the incinerator area and the south-central portion of the groundwater plume. CS3 was used to evaluate central portion of the plume. CS4 was used to evaluate conditions perpendicular to the groundwater flow direction. CS5 was used to evaluate the relationship between extraction well EW-2 and surrounding wells. Cross sections CS1, CS2, CS3, and CS5 generally proceed in the direction of groundwater flow, from the east toward Wildcat Creek.

The cross sections are generalized to show the three major hydrogeologic zones identified above. Data were taken from the newly installed wells and borings, and from historic boring logs, as available. Elevations for the top of bedrock, the top of PWR, and groundwater were each processed using Kriging interpolation methods to develop elevation contours across the site for these features. The cross sections were then prepared from the resulting elevations. **Appendix I** includes the elevation contour maps used to prepare the cross-sections. Each cross section was separated into two figures, one containing chlorinated ethenes/ethanes (CEE) concentrations and one containing BTEX/chlorinated benzenes (CB) concentrations. These concentrations are discussed in later subsections. The observed hydrogeology is discussed below.

#### *Cross Section 1*

CS1 is shown in **Figures 4-4** and **4-5**. This section extends from west to east on the north end of the warehouse, crossing through the Drum Processing, Drum Packaging, and former Burn Pits areas before crossing Wildcat Creek to the east. Just east of the warehouse building, the bedrock elevation decreases sharply to RIMW-22, then increases again towards Wildcat Creek. It should be recognized that the interpretation depicted of the bedrock surface associated with RIMW-22 could be exaggerated. This low point in the bedrock surface may not be as laterally extensive as shown in the cross sections. Groundwater flow along this section is toward Wildcat Creek. It should be noted that the water table surface is in the PWR in the west portion and in the regolith in the east portion.

#### *Cross Section 2*

CS2 (**Figure 4-6** and **Figure 4-7**) extends from west to east and crosses the Drum Storage/Solvent Recovery, Blend Tanks Overflow, Solvent Ditch, and Fuel Oil areas

before crossing Wildcat Creek. CS2 has a bedrock surface depression similar to that in CS1, although not as drastic. Just east of the warehouse building, the bedrock elevation decreases to RIMW-26, then increases again towards Wildcat Creek. The groundwater flow direction is toward Wildcat Creek in this section. The saprolite layer appears to be thicker in CS-2 than in CS-1 and the water table surface resides entirely in the regolith rather than having portions in PWR.

#### ***Cross Section 3***

CS3 is shown in **Figures 4-8 and 4-9**. This section extends from northwest to southeast and crosses the Drum Repackaging and Fire, Incinerator, and the Fuel Oil areas before crossing Wildcat Creek. CS3 indicates that the bedrock surface decreases downgradient of the warehouse building and increases towards Wildcat Creek. Surface elevation decreases approximately 20 feet from the west boundary to the creek. The groundwater flow in this section is toward Wildcat Creek.

#### ***Cross Section 4***

CS4 runs from south to north as shown in **Figures 4-10 and 4-11**. This section is generally drawn perpendicular to the direction of groundwater flow and extends through the Fuel Oil and Drum Storage and Management areas. The hydrogeology indicates that the wells on this section are screened in either PWR or bedrock. Bedrock elevation decreases slightly near EW-2 then increases slightly before dropping dramatically just east of the north end of the warehouse.

#### ***Cross Section 5***

CS5, which is shown in **Figures 4-12 and 4-13**, runs from west-northwest to east-southeast. This section crosses through the Drum Repackaging and Fire Area and extends just south of the former Incinerator location and Fuel Oil area. Similar to CS1 and, CS2, and CS3, the bedrock surface elevation decreases east of the warehouse before increasing towards Wildcat Creek. The groundwater flow in this section is toward Wildcat Creek.

## **4.2 Environmental Media Sampling**

This section presents the analytical results for sampling conducted during the RI for soil, groundwater, and sediment. As discussed further below, the data for soil and groundwater are presented based on potential areas of concern developed using historical reports, historical data, and data collected during the RI.

### **4.2.1 Soil**

This subsection presents the results of soil sampling activities, which were conducted during Phase I and Phase II of the RI. **Table 4-5** presents a summary of the compounds detected in soil above screening criteria. The sampling locations are shown in Figure 3-1. All soil analytical results are presented in **Appendix D**, Table D-1.

Soil sampling results for semi-volatile organic compounds (SVOCs) and metals are also provided in Table 4-5. The SVOC results show that only one location (RISB-49) had concentrations detected above SSLs, and no locations with concentrations detected above PRGs. Four metals (arsenic, chromium, nickel, and thallium) were detected above PRGs and SSLs at several locations in soil. No locations had detections of metals above both criteria.

The sample locations with VOC detections above either the industrial soil PRGs or SSLs with a dilution attenuation factor (DAF) of 20 are presented in **Figure 4-14** for surface soil and **Figure 4-15** for subsurface soil, with total organic concentrations (separated by class of VOC) shown for each of these locations. Three classes of VOCs and their typical degradation products were identified as having the highest concentrations in both soil and groundwater site wide:

- BTEX – Benzene, toluene, ethylbenzene, and toluene.
- Chlorinated ethenes and ethanes (CEE)– Chloroethane; 1,1-dichloroethane; 1,2-dichloroethane; 1,1-dichloroethene; cis-1,2-dichloroethene; 1,1,2,2-tetrachloroethane; tetrachloroethene; 1,1,1-trichloroethane; trichloroethene; 1,1,2-trichloroethane; and vinyl chloride.
- Chlorinated benzenes (CB)– Chlorobenzene; 1,2-dichlorobenzene; 1,3-dichlorobenzene; 1,4-dichlorobenzene; 1,2,3-trichlorobenzene; and 1,2,4-trichlorobenzene.

Although other compounds were detected on site, they were generally coupled with higher concentrations of compounds from one of the three identified classes. It is also anticipated that remedial alternatives will be focused on these three classes of compounds.

In addition to segregation of VOC results by class, soil results were grouped into four areas of concern based on observed concentrations and historical information about releases. These areas are shown on Figure 4-15 and summarized below:

- Soil Area #1 – Warehouse (Drum Storage and Management) Area. This area is located on the northern end of the warehouse and contains the former East Drum Storage, Drum Receiving, and Drum Packaging areas.
- Soil Area #2 - Incinerator /Drum Repackaging Area. This area contains both the southern end of the warehouse (Drum Repackaging and Fire area) and the former incinerator area southeast of the warehouse.
- Soil Area #3 – Solvent Ditch Area. This area contains the former solvent ditch area. This area is also located southeast of the former Blend Tanks Overflow area.

- Soil Area #4 – South Drum Storage Area. This area is the furthest southeast on the site and although this area does not include any previously identified SWMUs, it is adjacent to the former storm water pond and a former drum storage area.

The soil results for each VOC class and area of concern are discussed below.

#### **4.2.1.1 Soil Area #1 - Warehouse (Drum Management and Storage) Area**

Soil samples collected in this area include RISB-16, -20, -21, -30, -66 and RIMW-6 and -19. Additional locations near this area include RISB-9, -17, -31, -32, -38, and -67.

Surface soil (0-1 ft or 0-5 ft bls) samples had detections above criteria for CEE at RISB-16 and RIMW-6 in this area. These locations each had over 1 mg/kg total CEE, with cis-1,2-dichloroethene (DCE) being predominant at RIMW-6 (3.4 mg/kg) and tetrachloroethene at RISB-16 (2.8 mg/kg). Neither BTEX nor CB was detected in this area.

Subsurface soil samples had detections above screening criteria for CEE in 5 of 12 subsurface sampling locations. BTEX and CB were not detected above screening criteria in subsurface samples from this area. The highest concentrations of CEE (30.4 mg/kg) were detected at RIMW-6 from 4-6 feet bls.

#### **4.2.1.2 Soil Area #2 - Incinerator / Drum Repackaging Area**

Soil samples collected in this area include RISB-6, -11, -12, -13, -18, -19, -23, -26, -45, -46, -52, -61, -62, -63, -64, and -65 and RIMW-1. Additional locations near this area include RISB-7 and RISB-51.

Surface soil samples (0-1 and 0-5 ft bls) had detections above soil criteria for BTEX in four locations, for CEE in seven locations, and for CB in one location. The highest concentrations of CEE and BTEX were detected in RISB-64 (17 mg/kg) and RISB-65 (65 mg/kg), respectively. Both of these locations were in the drum storage area of the warehouse. The highest concentration of CB was detected in RISB-46 (32 mg/kg). CB were only detected in the incinerator area and not in the warehouse storage area.

Subsurface soil samples had detections above screening criteria for BTEX in four locations, for CEE in 12 locations, and for CB in one location. The highest concentrations were detected at RISB-64 for CEE (291 mg/kg), RISB-12 for BTEX (2,700 mg/kg), and at RISB-18 for CB (27 mg/kg). The BTEX and CB concentrations were detected at these levels from 1-5 feet bls, and CEE were detected at their highest levels in this area from 5-10 feet bls. BTEX and CEE were detected above screening levels at depths up to 20 feet bls. The estimated depth to groundwater in regolith is between 17 and 20 feet bls in this area. Site wide, the highest concentrations were detected in this area for all three VOC classes.

#### 4.2.1.3 Soil Area #3 - Solvent Ditch Area

Soil samples collected in the Solvent Ditch area include RISB-28, 29, -50, -59, and RIMW-8. Additional locations near this area include RISB-27 and RIMW-5.

No concentrations were detected above soil criteria for surface soil samples (0-1 ft bls) collected from this area. Subsurface soil samples had detections above screening criteria for BTEX in one location and for CEE in five locations. CB were not detected above screening criteria in this area. The highest concentrations were detected at RISB-29 for BTEX (590 mg/kg) and RIMW-8 for CEE (6 mg/kg). CEE were detected above criteria at depths up to 20 feet bls (RIMW-5). The estimated depth to groundwater in RIMW-5 is approximately 20 feet bls.

#### 4.2.1.4 Soil Area #4 - South Drum Storage Area

The South Drum Storage area includes soil locations RISB-2, -25, -47, and -57. Surrounding locations RISB-4, -24, -39, -48, and -58 are also being evaluated for this area.

In surface soils (0-1 feet bls), CEE was detected above soil criteria at RISB-2. The total CEE concentration at this location was 0.14 mg/kg. BTEX and CB were not detected above screening criteria in surface soil samples from this area.

Subsurface soil samples had detections above screening criteria for BTEX in one location and for CEE in four locations. CB were not detected above screening criteria in this area. The highest concentration observed for total CEE was 50 mg/kg at RISB-25 from 17-20 feet bls. BTEX was detected at RISB-2 (5.9 mg/kg) from 9-13 feet bls and was also detected from 17-21 feet bls at 4.2 mg/kg. The depth to groundwater is approximately 20-21 feet bls in this area.

### 4.2.2 Groundwater

Table 4-6 presents the compounds detected in groundwater above screening criteria during the RI. Groundwater sample (monitor well) locations are shown in Figure 3-1. All groundwater analytical results are presented in Appendix D, Table D-2.

Groundwater samples were collected for analysis of SVOCs and metals on select wells installed during Phase II (RIMW-1, RIMW-3 through RIMW-16, RIMW-18, RIMW-19, and RIPZ-3). These analyses were performed to validate whether or not the groundwater plume of concern is associated with VOCs only. Additional groundwater monitor wells were installed in Phase III based solely on VOC detections, and therefore only VOC analyses were performed on Phase III wells (RIMW-20 through RIMW-30). Groundwater sampling results for SVOCs and metals are provided in Table 4-6. The SVOC results show that only one location (RIMW-8) had detections of SVOCs at reportable concentrations.

VOC concentration contours in groundwater were estimated for the three VOC classes (BTEX, chlorinated ethenes/ethanes, and chlorinated benzenes) in both

regolith/PWR and bedrock. These concentration contour maps are shown in **Figures 4-16 through 4-21**.

Based on information derived from the cross sections in Section 4-1 and the concentration contours, groundwater areas of concern were identified. These areas of concern are shown on **Figure 4-22** and include the following:

- **GW Area #1 - Incinerator / Drum Repackaging Area** – The incinerator area was chosen because this is the area in regolith (shallow) groundwater and soil with the highest concentrations of chlorinated benzenes (6.9 mg/L in MW-123A). This area also includes the southern end of the warehouse where soil concentrations of BTEX exceed 1,000 mg/kg and CEE soil concentrations are close to 300 mg/kg.
- **GW Area #2 - Solvent Ditch Area** – Groundwater in the solvent ditch area contains the highest concentrations of chlorinated ethenes in regolith, and the highest concentrations of all three VOC classes were detected in bedrock in this area. This area also appears to contribute high concentrations of VOCs to bedrock groundwater (refer to cross sections). This area extends into the North Drum Storage location because detected compounds in groundwater there are consistent with concentrations in the solvent area, possibly indicating one source or contiguous sources.
- **GW Area #3 - Burn Pits** – Although a removal action previously occurred in this area in 1983, groundwater concentrations in this area do not suggest that VOCs in this area are a result of migration from other areas.
- **GW Area #4 - Fuel Oil Area** – The fuel oil area remains an area of concern because free product is still present in this location.

The groundwater results for each VOC class and area of concern are discussed below. Please note that when reviewing the bedrock groundwater data, some bedrock wells installed during Phase III in September 2007 may not have been fully equilibrated when they were sampled. Bedrock wells RIMW-21, -23, -26, and -28 did not recharge adequately during development of the wells. In addition, when sampling these wells, they became dry before purging three well volumes.

#### **4.2.2.1 GW Area #1 - Incinerator / Drum Repackaging Area**

##### ***Shallow Horizon***

The shallow wells that are in the Incinerator Area include RIMW-1, RIMW-3, RIMW-11, MW-123A, and OB-109. All wells except RIMW-11 and OB-109 had detections of benzene above MCLs but total BTEX did not exceed 150 ug/L for any well.

CEE concentrations were detected above MCLs for all wells in this area. RIMW-11 had over 680 ug/L of CEE, which consisted primarily of tetrachloroethene (PCE) and trichloroethane (TCA) degradation product dichloroethane (DCA). On the southeast

side of the warehouse, RIMW-1 had 21,000 ug/L of CEE, which consisted mainly of trichloroethene (TCE), PCE, and DCE. Also on the southeast side of the warehouse, OB-109 had 68 ug/L of CEE, which consisted mainly of 1,2-DCE. On the north end of the drum repackaging area at RIMW-3, the total concentration of CEE was 14,000 ug/L and contained 13,000 ug/L of 1,2-DCA. Near the former incinerator, MW-123A had a total CEE concentration of 6,250 ug/L and contained 4,900 ug/L of 1,2-DCA and 1,100 ug/L of 1,2-DCE. PCE was not detected in this well, unlike the three up gradient wells.

None of the wells in the drum repackaging area (RIMW-1, RIMW-3, and RIMW-11) had concentrations of chlorinated benzenes exceeding MCLs. MW-123A had over 6,900 ug/L of CB, with concentrations over 1,000 ug/L for 1,2-dichlorobenzene, 1,4-dichlorobenzene, and chlorobenzene.

#### ***Bedrock Horizon***

The bedrock wells in the Incinerator and Drum Repackaging Area include RIMW-18, OB-109B, and RIMW-28. MCLs were not exceeded for BTEX in any of these wells.

CEE concentrations exceeded MCLs for at least one constituent in all three wells. Total CEE in OB-109B was 347 ug/L and consisted mainly of PCE (210 ug/L). RIMW-18 has a total CEE concentration of 33.5 ug/L and consisted primarily of PCE. RIMW-28 had a total CEE concentration of 78 ug/L and contained mainly 1,2-DCA and 1,2-DCE.

#### **4.2.2.2 GW Area #2 - Solvent Ditch Area**

##### ***Shallow Horizon***

The wells near this area that are screened in regolith are RIMW-4, -5, -6, -8, -16, OB-110A, OB-8A, P-1, and P-3. BTEX concentrations are highest on site in this area (with exception to the fuel oil area where free product is present), with total BTEX concentrations in the mg/L range for RIMW-8, OB-8A, and OB-110A. Benzene was also above MCLs for RIMW-4, -5, -6, and -16, but overall BTEX concentrations in these wells were below 0.1 mg/L. All BTEX compounds were below MCLs for P-1 and P-3.

CEE concentrations in the Solvent Ditch Area were higher than BTEX, and total CEE concentrations were above 1 mg/L for all wells. The highest concentrations of CEE were 53 mg/L and 89 mg/L at RIMW-5 and RIMW-8, respectively. CEE concentrations included parent compounds 1,1,1-TCA, PCE, and TCE in all wells, indicating that multiple parent compounds (PCE and 1,1,1-TCA) are present in this area.

Chlorinated benzene concentrations were detected in all of the wells in this area except RIMW-6. Chlorobenzene was the only chlorinated benzene detected above MCLs (in wells RIMW-4, RIMW-8, and OB-8A).

##### ***Bedrock Horizon***

Bedrock wells in this area include RIMW-25 (located just south of the solvent ditch), OB-110B (also south of the solvent ditch), RIMW-19 (just north of the ditch), and

RIMW-22 (northeast of RIMW-19). The top of bedrock for these wells are 495 ft, 492 ft, 479 ft, and 412 ft for RIMW-25, OB-110B, RIMW-19, and RIMW-22, respectively. Although a cross section was not made for this specific area, top of bedrock elevations noted above indicate that there is a steep gradient in bedrock elevation from RIMW-25 to RIMW-22.

BTEX concentrations were detected 14 mg/L at RIMW-25, the highest concentrations in bedrock. However, BTEX were not detected above MCLs in the three other wells. CEE concentrations were also the highest on site in bedrock at RIMW-25 (11 mg/L). CEE were detected above MCLs in the other three wells as well. CB concentrations follow a similar trend with CB concentrations the highest on site in bedrock at RIMW-25 (2.3 mg/L). CB were not detected in the other three wells.

#### **4.2.2.3 GW Area #3 - Burn Pits Area**

##### ***Shallow Horizon***

The shallow wells that are near the former Burn Pit Area include BP-1A, MW-103, and RIMW-24. TCE was detected above its MCL in BP-1A but no CEE compounds were detected above MCLs in upgradient well MW-103. RIMW-24 had concentrations of PCE, TCE, 1,2-DCE, and 1,1-DCE above MCLs, and in general, these concentrations were at least ten times higher than the concentrations in BP-1A.

Bedrock elevations shown in Cross Section CS1 (Figure 4-4) indicate that depth to bedrock rises sharply from RIMW-16 to BP-1A although the depth to bedrock in RIMW-24 (Figure 4-6) is similar to BP-1A. The concentrations detected in BP-1A appear to indicate that either a source exists in this area or that chlorinated ethenes have a preferential flow path in a cross gradient direction from RIMW-24 to BP-1A. Neither BTEX nor chlorinated benzenes were detected above MCLs in this area.

##### ***Bedrock Horizon***

The bedrock wells near the Burn Pit Area include EW-3 (extraction well), BP-1B (screened in PWR and bedrock), and RIW-23. PCE, TCE, 1,2-DCE, and 1,2-DCA were detected above MCLs in EW-3 (Figure 4-5), and similarly 1,1-DCE, PCE, TCE, 1,2-DCE, and vinyl chloride (VC) were all detected above MCLs for adjacent well BP-1B. The concentrations in EW-3 and BP-1B detected are also similar in magnitude. No VOC concentrations exceeded MCLs in RIMW-23. Neither BTEX nor chlorinated benzenes were detected above MCLs in this area.

Downgradient of the burn pit area, similar CEEs (PCE, TCE, 1,2-DCE) were detected in bedrock well MW-121B across the creek. This is the only location where MCLs are exceeded across the creek as TCE was detected at 7.5 ug/L.



#### 4.2.2.4 GW Area #4 - Fuel Oil Area

##### *Shallow Horizon*

The shallow monitor wells in the Free Product Area include MW-104, MW-118, MW-119, RIMW-27, RIPZ-3, OB-11, OB-12, OB-13, OB-21, OB-22, OB-23, OB-900, OB-901, OB-902, and P-2.

Product thickness data collected in January 2007 (shown in Table 4-7) indicate that the greatest thickness of oil product in the fuel oil area is around wells OB-12, -13, -22, and -900. These are also the areas with the highest concentrations of BTEX. BTEX concentrations do not appear to extend very far in the downgradient direction, as concentrations are orders of magnitude lower at MW-118, and are below MCLs at MW-119 and RIMW-27.

Concentrations in CEE are below MCLs in the area of highest fuel oil thickness. Significant degradation may be occurring at this location because of the abundance of electron donor (as BTEX). The closest bedrock well, RIMW-26, also is below MCLs for all CEE compounds, indicating that either the CEE observed in the upgradient wells is not "sinking" to the bedrock horizon, degradation is occurring at this well, or preferential flow paths do not transmit water from the fuel oil area to this well. MCLs are exceeded for CEE only in downgradient well RIMW-27. Chlorinated benzene concentrations are also below MCLs in regolith in this area.

##### *Bedrock Horizon*

Only RIMW-26 is screened in bedrock in the immediate vicinity of the fuel oil area. Concentrations of all VOCs were below MCLs in this well. RIMW-29, located southeast of the fuel oil area, contained 1,2-DCA, 1,2-DCE, PCE, TCE, and VC above MCLs.

#### 4.2.3 Surface Soil Sampling across Wildcat Creek

The surface soil sampling locations in the undeveloped portion of the site across Wildcat Creek are shown in Figure 3-2. The only constituent detected above soil screening criteria was arsenic. This compound was detected in all ten locations at approximately the same concentration as that detected in background sample RI-BCK1. The highest arsenic concentration detected was 2.5 mg/kg at RISS-4, and the arsenic concentration at RI-BCK1 was 1.6 mg/kg.

#### 4.2.4 Sediment Sampling

Sediment samples were collected as described in Section 3. Sediment sample detections above ESVs are shown in Table 4-8. Complete analytical results are provided in Appendix D, Table D-3.

##### 4.2.4.1 Catch Basin / Water Collection Area Sampling

One catch basin was sampled on site at RICB-3. This location was upgradient of stormwater outflow No. 2, as shown in Figure 3-2. RICB-3 was sampled for VOC,

SVOC, and metals analyses. Bis(2-ethylhexyl)phthalate and several metals were detected above ESVs at this location.

An additional sediment sample (RI-WASTE) was obtained from a water collection area within the warehouse building at the direction of SCDHEC. The sample was also analyzed for VOCs, SVOCs, and metals. Several SVOCs and metals were detected above ESVs at this location, as shown in Table 4-8.

#### 4.2.4.2 Creek Sediment Sampling

Five sediment samples were collected along the two creeks that border the main area of the site, and one background sample was collected from each creek. The locations of each sample correspond to a stormwater outflow from the site, as shown in Figure 3-2. Some polycyclic aromatic hydrocarbons (PAHs) were detected above screening criteria at these locations. However, the highest observed concentrations of PAHs were detected in the background sample (RISD-WCBK) collected from Wildcat Creek. Three metals (copper, lead, and mercury) were also detected above ESVs at a few creek sediment locations. These metals were not detected in the background sampling locations above ESVs.

### 4.3 Hydraulic Analysis

This section presents the results of the hydraulic analysis conducted during Phase II of the RI. The objective of the hydraulic analysis of the aquifer was to provide engineering data to evaluate groundwater remediation technologies. To do this, the extraction system was turned off for two weeks so that the aquifer could return to static (non-pumping) equilibrium. Site-wide groundwater elevations were collected prior to and following the equilibration period.

Once post-equilibration groundwater levels were recorded, a series of aquifer tests were conducted at wells EW-2 and EW-3. Based on analysis of the potentiometric surface data and pumping data, information was derived to estimate extraction well capacities and aquifer transmissivity. Regolith and bedrock potentiometric surfaces were also prepared from the data.

#### 4.3.1 Potentiometric Surface

As stated above, site-wide groundwater elevations were collected before and after aquifer equilibrium occurred. Figures 4-23 and 4-24 show the potentiometric surfaces in regolith pre- and post-equilibrium, respectively. The groundwater elevations in Figure 4-23 indicate that pumping at EW-2 has an effect on regolith groundwater, but the large variations between MW-119/RIPZ-3 and MW-113A and MW-114 indicate that the system is not in equilibrium because of inconsistent pumping that preceded the data collection event.

Immediately prior to the equilibrium period, the extraction wells were operating intermittently, with the pumps running at a flow rate greater than the aquifer could

supply. Therefore, the pumps would cavitate, with flow rates varying between 0 and 6 gpm. This caused the groundwater elevations in the aquifer to be in a constant state of flux. The pre-equilibration groundwater potentiometric surface maps were not evaluated in detail for these reasons. The September 2007 potentiometric surface maps (Figures 4-1 and 4-2) are used to describe groundwater flow patterns during pumping conditions.

Post-equilibrium groundwater maps are shown in **Figures 4-25 and 4-26**. In the regolith, it appears that equilibrium still had not been reached based on the variations in groundwater levels between MW-119/RIPZ-3 and MW-113A and MW-114. However, it is noteworthy that the hydraulic gradient is lower in this area than in the rest of the site, which may indicate an area of higher transmissivity. Post-equilibrium bedrock elevations show a similar pattern to regolith, with groundwater elevations relatively flat between MW-110B, MW-113B, and MW-120B.

### 4.3.2 Aquifer Performance Tests

Aquifer performance test (APT) results for EW-2 and EW-3 are shown in Tables 4-9 and 4-10, respectively. APT results are also included in **Appendix E**. The aquifer performance tests were performed as described in Section 3 and resulted in estimated aquifer transmissivities for different wells surrounding the extraction wells. The aquifer test data were analyzed according to the Theis method. Data curves were also prepared for qualitative comparisons to other type curves for leaky, delayed yield, and fractured rock aquifers. However, the magnitude of the “noise” in the water level data generally masked the transient effects of these aquifer variations, if such variations were present at all.

The well capacity test for EW-2 shown in **Figure 4-27** indicates a flow rate of about 3 gpm is sustainable. The APT at EW-2 was conducted at a flow rate of 2.7 gpm. EW-2 APT results indicate that EW-2 pumping has an influence on wells that are over 200 feet away, indicating that hydraulic conductivity in the area is moderately high. However, it appears that preferential flow paths are present because PWR well RIPZ-3 has an estimated transmissivity that is almost ten times higher than MW-118, which is located approximately between EW-2 and RIPZ-3. This indicates that although there is hydraulic communication between saprolite and PWR, they differ in transmissivity, and preferential pathways may be present in this area. The transmissivity observed at RIMW-14 also indicates that there is communication between PWR and bedrock in this area.

The well capacity test results for EW-3 presented in **Figure 4-28** indicate that a flow rate of about 3.5 gpm is sustainable. The APT at EW-3 was conducted at a flow rate of 3 gpm. EW-3 APT results yielded similar results to EW-2, except that two of the wells did not appear to have significant effects from the pump tests. One of these wells was RIMW-15, which is screened in bedrock, is lower than any other well in the test, and was over 200 feet away. The other well that did not respond to the test was MW-120B, located across the creek and approximately 300 feet away from EW-3.

These results indicate that pumping of EW-3 does not have a radius of influence over 225 feet. Pumping at EW-3 does appear to be influencing wells in the shallow zone that are within 100 feet. The data also indicate communication between regolith and bedrock in this area.

## **4.4 MPE Pilot Test**

This section presents the results of two short term MPE pilot tests performed during Phase II activities by KEMRON Environmental Services, Inc. (KEMRON). The MPE tests are described in Section 3. One test was performed in a chlorinated VOC source area (solvent ditch area) and another was performed in the fuel oil source area as shown in Figure 3-6. KEMRON's full MPE report is provided as **Appendix F**.

### **4.4.1 Solvent Ditch Area**

The results from the first pilot test indicate that MPE in this area may capture VOCs in the vadose zone within a 50-foot radius. Approximately 580 gallons of water were extracted during the 6-hour pilot test. However, less than 0.01 lb of VOCs were captured in the vapor phase during this time.

### **4.4.2 Fuel Oil Area**

The results from this pilot study indicated that MPE in this area would have a radius of influence of 50-75 feet from the extraction well in the vadose zone. Approximately 900 gallons of water were extracted during the eight hour test. Additionally, the VOC extraction rate from the vapor was approximately 3.8 lbs/day at the higher induced vacuum pressure.

## **4.5 Biochemical and Geochemical Data**

Biogeochemical and geochemical data were collected during Phase II activities to support the evaluation of remedial alternatives during the FS. The results from the biochemical and geochemical data analysis are presented in **Table 4-11**.

The biochemical and geochemical data collected indicate that methane reducing conditions exist on the site in regolith in the Incinerator (MW-123A), Solvent Ditch (OB-110A), and Fuel Oil (OB-11) Areas.

Wells in all other areas, including bedrock wells in the Incinerator, Solvent Ditch, and Fuel Oil Areas, did not appear to be methane reducing.

## **4.6 Monitor Well Inventory**

The results of the well inventorying task are shown on Table 4-4. This table includes well construction details, free product information, and groundwater levels from September 2007. The table also identifies whether certain parameter classes (e.g., VOCs) were historically detected in each well. Some of the well construction data could not be verified because documentation could not be found and/or conflicting

data existed between two different sets of records. Some of the data presented in the table cannot be verified without additional field verification, such as using a downhole camera.

The wells in Table 4-4 are shown to be in one of three geologic zones: regolith, PWR, and bedrock. As previously mentioned, the regolith and PWR zones are believed to be within the same hydrogeologic zone (i.e., in full hydraulic connection), and these two zones are referred to collectively as the shallow zone.

Some wells were reclassified during this task based on information found in available boring logs, geophysical logs, and/or well construction details. For example, MW-113B and MW-115B were reclassified from bedrock wells to PWR-Bedrock (or transition) wells. MW-113B includes saprolite, fractures, and one weathered rock layer to a depth of about 42 feet based on its geophysical log. The boring log contains insufficient detail to otherwise make a determination. The well sand pack is from 30.5 feet to 48 feet, placing it apparently in the PWR. Similarly, drilling for MW-115B encountered dense gabbro at a depth of about 29 feet based on the geophysical log and 32 feet based on the drilling notes. The boring log contains insufficient detail to otherwise make a determination. The well sand pack is from 19 feet to 34 feet, placing it apparently in the PWR.

## **4.7 Data Validation and Quality Control Summary**

As part of the RI, CDM performed data validation on the data received from Analytical Services, Inc. The validation activities were conducted in accordance with the USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Organic Data Review (October 1999) (organic guidelines) and USEPA CLP National Functional Guidelines for Inorganic Data Review (July 2002) (inorganic guidelines), and any applicable specific analytical method guidelines.

As required by the Quality Assurance Project Plan (CDM, December 2006), 90% of the data were evaluated (Level III) and one of the CLP data packages (approximately 10% of the data) was validated (Level IV) following the organic guidelines.

### **4.7.1 Data Usability Summary**

As a result of the data evaluation performed by CDM on the analytical data, some results were qualified as estimated "J" or "UJ", or rejected "R" because of one or more field or laboratory quality control (QC) outliers. The qualified data should be considered estimated and used with caution. The rejected data are not usable for project objectives. However, these data represent a very small population of the total data set, and all other RI analytical data are considered usable.

The data presented in Tables 4-5, 4-6, 4-8, and Appendix D are as reported by the laboratory. The qualifiers to be applied to these data based on the data validation are summarized below. Rejected data were not carried forward into the risk assessment.

## 4.7.2 Evaluation Procedure

The following quality control items were evaluated according to the applicable organic and inorganic guidelines to determine the quality of analytical data provided during the investigation. The non-CLP laboratory data packages were summary only (Level III), so not all quality control items could be evaluated for those data packages. The items evaluated include:

- Holding times
- Method detection limits
- Laboratory blanks
- Laboratory control samples
- Matrix spikes/matrix spike duplicates
- Inductively Coupled Plasma (ICP) Serial Dilution
- Laboratory duplicates/precision
- Surrogate recoveries
- Calibrations (organic only)
- Preservation criteria
- Internal standards
- ICP Interference Check Samples

In addition to the above items, CDM also evaluated the results of field duplicate samples, trip blanks, and equipment blanks. The individual data evaluation reports are included in **Appendix G**. The qualified Form I's are included on the enclosed CD-ROM.

## 4.7.3 Data Quality Indicators

The items identified for evaluation were grouped in terms of the quantitative data quality indicators (DQIs). These include precision, accuracy, completeness, and sensitivity. In addition, qualitative DQIs including representativeness and comparability were also evaluated, as summarized below.

### 4.7.3.1 Precision

The precision of a measurement is an expression of mutual agreement among individual measurements taken under prescribed similar conditions. Precision is quantitative and most often expressed in terms of relative percent difference (RPD). Precision of reported results is a function of inherent field-related variability plus laboratory analytical variability. The acceptable RPD limit for water field duplicates for this project is less than 20% and less than 30% for soil samples.

#### *Field Duplicate Precision*

Field duplicate samples were collected to provide a measure of the contribution to overall variability of field-related sources. During the RI, 22 field duplicate samples were collected:

<u>Duplicate</u>	<u>Parent Sample</u>
<i>Groundwater Samples</i>	
MW-1175	MW-117
RIMW-54	RIMW-4
RIMW-55	RIMW-5
RIMW-58	RIMW-8

RIMW-59	RIMW-9
RIMW-515	RIMW-15
DUP-01	RIMW-25
DUP-02	RIMW-27
RIPZ-53	RIPZ-3
<i>Soil Samples</i>	
RIMW-51:12-14	RIMW-1 (12-14 ft)
RIMW-58:10-12	RIMW-8 (10-12 ft)
RISB-92	RISB-2 (0-1 ft)
RISB913	RISB-13 (5-9 ft)
RISB914	RISB-14 (5-9 ft)
RISB-533	RISB-33 (17-20 ft)
RISB935	RISB-35 (5-9 ft)
RISB-946	RISB-46 (0-1 ft)
RISB-951	RISB-51 (9-13 ft)
RISB-559:12-14	RISB-59 (12-14 ft)
RISB-562:12-14	RISB-62 (12-14 ft)
RISS-510	RISS-10 (0-1 ft)
<i>Sediment Samples</i>	
RISD-54	RISD-4

According to the guidelines, the field duplicate criteria between the sample pair results for water samples is a RPD < 20, and for soil samples < 35. If the parent sample or duplicate sample result is less than 5 times the Contract Required Quantitation Limit (CRQL) for waters and less than 2 times the CRQL for soils, then the control limit becomes the absolute difference of the CRQL. If the difference between the parent sample and the duplicate sample results is less than the CRQL (waters) or less than 2 times the CRQL (soils), then no qualifications are required. An RPD is not calculated if one sample result for either the duplicate or the parent sample is non-detect. **Table 4-12** shows the RPDs outside of appropriate control limits.

#### ***Laboratory Duplicate Precision***

Contribution of laboratory-related sources to overall variability was measured by calculating the RPD between matrix spike and matrix spike duplicate (MS/MSD) results, laboratory duplicate results, and laboratory control sample and laboratory control sample duplicate (LCS/LCSD) results, where available.

**Table 4-13** contains a summary of laboratory precision outliers. All samples of similar matrix were qualified estimated "J" or "UJ" based on laboratory precision results. Individual qualified sample results are on the enclosed CD-ROM.

#### **4.7.3.2 Accuracy**

Accuracy is defined as the degree of agreement between a measurement and an accepted reference or true value and is a measure of bias in a system. Use of the specified analytical methods, evaluation of blank contamination, verification of acceptable instrument calibration, and adherence to the required sample holding

times and chain-of-custody procedures also help ensure the accuracy of the resultant data.

Each analytical data package included either the original signed and executed chain-of-custody forms or a copy, indicating that custody of the samples was maintained as required from sample collection to receipt at the laboratory and during sample analysis.

#### **4.7.3.2.1 Evaluation of Blanks**

##### ***Trip Blanks***

Trip blanks were prepared by the laboratory, transported to the field with the VOC sample containers, and returned to the laboratory with the VOC samples for analysis. Analysis of trip blanks is performed to assess whether cross-over contamination is occurring between samples during handling and transport. Detected concentrations of toluene, acetone, methylene chloride, 1,2-dichloroethane, trichloroethene, and vinyl chloride were present in some of the trip blanks. Sample results were qualified when the sample result was less than 5 times the value detected in the trip blank. **Table 4-14** summarizes the sample result qualified on the basis of a trip blank.

Trip blanks were not included with samples in SDG 229401, SDG 237552, SDG 238041, SDG 238119, SDG 238907, and SDG 239396.

##### ***Method, Calibration, and Equipment Blanks***

Analysis of method blanks ensures that no carryover of contaminants between samples exists because of residual contamination on the instrument or from contaminants introduced in the laboratory. At least one method blank was prepared and analyzed with each batch of samples analyzed using each analytical method.

Several metals and VOCs were detected in the method blanks. Analyses were all method compliant in that target analytes were not detected in the method blanks or calibration blanks at levels greater than the reporting limits. Sample results were qualified when the sample result was less than 5 times the value detected in the blank.

The highest concentration detected in an applicable blank is used to determine this reportable concentration. This practice decreases the possibility of false positives, particularly at levels near the reporting limits. Calibration blanks for inorganic analyses were not provided with the data packages and hence were not evaluated. Equipment rinsate blank results were all non-detect.

**Table 4-15** summarizes the qualifiers applied on the basis of laboratory blanks.



#### 4.7.3.2.2 Laboratory Control Sample, Matrix Spike/Matrix Spike Duplicate, and Surrogate Recoveries

LCSs and MSs were prepared and analyzed with all applicable methods. System monitoring compounds, or surrogates, were also added to the organic analyses. Recoveries of these QC samples are discussed below.

Accuracy is quantitative and usually expressed as the percent recovery (%R) of a sample result. Acceptable QC limits are 80 to 120 percent for LCS recoveries and 75 to 125 percent for MS/MSD analyses for the inorganic methods. Organic method acceptable ranges are laboratory-defined based on past statistics maintained to document method performance.

##### *Laboratory Control Sample Recoveries*

LCSs were prepared for all sample analyses to evaluate the ability of the analytical process to recover a known concentration of an analyte. All LCS recoveries were within QC limits.

##### *Matrix Spike/ Matrix Spike Duplicate Recoveries*

MS and, for specific methods, MSDs were prepared for all applicable sample analyses to evaluate matrix interference effects. **Table 4-16** summarizes the MS/MSD outliers. Results listed in this table required qualification as estimated "J" or "UJ" as a result of recoveries outside the QC criteria. Undetected results were not qualified when MS/MSD recoveries were above the QC limit.

Organic analyses guidelines do not qualify sample results based on matrix spike recoveries. Some of the organic matrix spike recoveries were outside of appropriate criteria but no qualification is required.

For the inorganic analyses, qualifiers are applied to the appropriate associated samples for matrix spike recoveries that are outside of appropriate criteria. Qualifiers are not added when the sample concentration is greater than 4 times the matrix spike concentration. **Table 4-16** identifies the SDG and the affected analytes. Specific qualified samples are identified on the evaluation reports in Appendix G.

##### *Surrogate Recoveries*

Surrogate recoveries met accuracy criteria for all samples except for those listed in **Table 4-17**. Qualified sample results are included in Appendix G and on the enclosed CD-ROM.

The non-detect results for analytes associated with the surrogate tetrachloro-m-xylene in sample RISB-946 were rejected "R" and are not usable. The positive detected results were estimated "J" and are usable.

#### 4.7.3.2.3 Internal Standard Areas and Retention Times

Retention times and recoveries for the internal standards for SDG 249441 were within the acceptance limits. No internal standard information was provided with the other data packages for review.

#### 4.7.3.2.4 Instrument Calibration

Calibration criteria are method-defined. The laboratory followed the prescribed calibration techniques. Relative Response Factor (RRF) and Relative Standard Deviation or Percent Difference (%D) criteria were met for VOC and SVOC sample analyses except for those listed in **Table 4-18**. Qualified associated sample results are identified in Appendix G and on the enclosed CD-ROM. Calibration information was not provided for inorganic analyses; thus, no evaluation was performed. Specific calibration qualification details are included in Appendix G.

Some of the non-detect sample results for methyl acetate, bromomethane, and chloroethane were rejected "R" due to initial and continuing calibration. These results are not usable for project goals.

#### 4.7.3.2.5 Inductively Coupled Plasma Serial Dilution

An ICP serial dilution is to be performed for each batch of metal samples analyzed. The method limit of 10 percent difference between the sample and the serial dilution is defined as acceptable. This criterion is only applied to analytes greater than 50 times the instrument detection limit (IDL). All serial dilutions met required criteria for SDG 239401. No other serial dilution information was provided for the other data packages.

#### 4.7.3.3 Completeness

Completeness is a measure of the amount of usable data that are obtained compared to the amount that was expected to be obtained during project planning. Evaluating the precision and accuracy parameters (above) assessed the usability of the data. Those data that were evaluated and needed no qualification, or were qualified as estimated "J" or "UJ," are considered usable. Rejected data are not considered usable. The rejected non-detect results for methyl acetate, bromomethane, chloroethane, and the associated PCB sample results for RISB-946 are considered not usable. All other data are considered usable for its intended purposes.

#### 4.7.3.4 Sensitivity

Sensitivity is related to the ability to compare analytical results with project-specific levels of interest, such as cleanup levels or action levels. Analytical practical quantitation limits (PQLs) for the various sample analytes should be below the level of interest to allow an effective comparison. Required method detection limits are presented in the QAPP. The laboratory met the required sensitivity levels.

#### 4.7.3.5 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent: (1) a characteristic of a population, (2) parameter variations at a sampling point, and/or (3) an environmental condition. Representativeness is a qualitative parameter that addresses the proper design of the sampling plan and the absence of cross contamination. Good representativeness was achieved through:

- Careful, informed selection of sampling sites
- Selection of analytical parameters and methods that adequately define and characterize the extent of possible contamination and provide the required sensitivity
- Proper gathering and handling of samples to avoid interference and prevent contamination and loss
- Collection of a sufficient number of samples to allow representative characterization of the site

Representativeness is a consideration that was employed during data collection design, and the data that were collected during the field investigation are believed to be representative of actual field conditions. All data collected except for the rejected results are considered representative of the actual field conditions at the time of collection.

#### 4.7.4 Conclusion

In the course of data review, some "J" and "UJ" qualifiers were added to the results, indicating these data are estimated and should be used with caution. A small fraction of results was also rejected ("R") and is not usable for project objectives.

Appendix G presents the individual data evaluation reports. Qualified Form I's are included on the enclosed CD-ROM. Overall, the majority of the data were determined to be of acceptable quality for determining that data quality objectives (DQOs) were met and are representative of environmental conditions at the time of collection. The additional qualifiers added and the inability to use the rejected data are not expected to affect the evaluation of the nature and extent of contamination, the risk assessment, or the evaluation of remedial alternatives in the feasibility study.

# Section 5

## Human Health Risk Assessment

### 5.1 Introduction

This section presents the human health risk assessment (HHRA) for the PSC site. The assessment is based on concentrations of contaminants detected in soil and groundwater at the site, exposure assumptions, and toxicity information, which together are used to characterize risks to human receptors. Risks are estimated based on existing (baseline) conditions in the absence of any further remedial action or institutional controls.

The objective of the HHRA is to assess potential current and foreseeable future risks associated with exposures to potential human receptors including workers, residents, trespassers, and recreational receptors at the site. Specifically, the objectives of the HHRA are to:

- Identify chemicals of potential concern (COPCs).
- Identify human receptors of concern.
- Evaluate all potentially complete exposure pathways.
- Determine the extent and likelihood of actual or potential risks/hazards to human health.
- Describe the uncertainty associated with the risk and hazard estimates.
- Help determine chemicals of concern (COCs) and whether additional response actions are necessary.

Exposures to soils and groundwater were evaluated quantitatively for relevant receptors. This HHRA estimates cancer and noncancer risks for all potentially complete exposure pathways. This HHRA is consistent with EPA's Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part A) (RAGS, EPA 1989) and is organized as follows:

- Section 5.2 - Data Summary;
- Section 5.3 - Selection of COPCs;
- Section 5.4 - Exposure Assessment;
- Section 5.5 - Toxicity Assessment;
- Section 5.6 - Risk Characterization;
- Section 5.7 - Uncertainty Assessment; and

- Section 5.8 – Summary and Conclusions.

## 5.2 Data Summary

Phase I, Phase II, and Phase III investigations included collection and analysis of samples from surface soil, subsurface soil, and groundwater. A small number of sediment samples were also collected but because of generally low detections, they were not used in the risk assessment. Details of the investigations and sample analyses are summarized and discussed in Sections 3 and 4. A summary of data used in this risk assessment is discussed below.

### 5.2.1 Surface Soil

Surface soil samples were collected at 71 locations (RISB-1 through -52, RISB-56 through -59 and RISB-61 through -67, RIMW-1, -5 through 8, -13, -19, and RIPZ-3) from varying depth intervals. For purposes of this characterization, all samples with a sampling depth beginning at ground surface (zero inches) to one foot below ground surface (bgs) were included in the surface soil data set. In general, each of the surface samples was sent to Analytical Services Inc. (ASI) for analysis of EPA's Target Compound List (TCL) of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs), and EPA's Target Analyte List (TAL) for metals. Two offsite locations (RI-BCK1 and RI-BCK2) were used as background samples and analyzed for TCL VOCs, SVOCs, and TAL metals. Three duplicate samples were collected from surface soil locations RISB-2, RISB-46, and RISS-10. Where duplicate samples were collected, the average concentration of the parent and duplicate sample was used as a representative concentration for that location.

Surface soil data are divided into two data sets to address current and future land uses. The dataset for assessing current land-use scenarios does not include sample locations RISB-11 through RISB-17, RISB-20, RISB-21, RISB-45, RISB-62 and RISB-64 through RISB-67. These locations are currently under a concrete foundation, precluding exposure. The dataset for assessing future land-use scenarios includes all surface soil samples, assuming the concrete foundation might not be maintained or could be removed in the future. Sampling locations are shown on Figures 3-1 through 3-4.

### 5.2.2 Subsurface Soil

Subsurface soil samples at 71 locations (RISB-1 through -52, RISB-56 through -59 and RISB-61 through -67, RIMW-1, -5 through 8, -13, -19, and RIPZ-3) were collected from varying depth intervals (one foot through a maximum depth of 27 feet bgs). Any sample with a beginning depth greater than one foot bgs was considered subsurface soil. However, samples collected from locations RISB-64, RISB-65, RISB-66, and RISB-67 were collected from zero to five feet bgs and were classified as subsurface soil. In general, each of the subsurface samples was sent to ASI for analysis of TCL VOCs, SVOCs, and TAL Metals. Some samples were also analyzed for PCBs. Two offsite locations (RI-BCK1 and RI-BCK2) were used as background samples and

analyzed for TCL VOCs, SVOCs, and TAL Metals. Nine duplicate samples were collected from subsurface soil locations RISB-13, RISB-14, RISB-33, RISB-35, RISB-51, RISB-59, RISB-62, RIMW-1, and RIMW-8. Where duplicate samples were collected, the average concentration of the parent and duplicate sample was used as a representative concentration for that location.

Surface soil and subsurface soil datasets are combined into one current/future dataset for evaluating risks to excavation workers who may come into contact with soil both at the surface and subsurface regardless of the presence of a concrete foundation. If construction work were to take place either currently or in the future, the foundation would be removed, exposing the construction worker to all soil. In addition, the current/future surface and subsurface dataset was used for the future resident scenario. If homes were to be erected, subsurface soil could be brought to the surface. The list of the surface and subsurface soil samples used in the risk assessment is provided in Appendix D tables, and sampling locations are shown on Figures 3-1 through 3-4.

Surface soil and subsurface soil datasets are combined and collectively referred to as "subsurface soil" for the remainder of the document for construction workers and residents who may come into contact with soil both at the surface and at depth.

### 5.2.3 Groundwater

The groundwater data set consists of analytical results from samples from 60 monitoring wells, including temporary wells. These wells are classified by various hydrologic units (i.e., saprolite, partially weathered rock (PWR), or bedrock) and are shown on Figure 3-1. All samples were analyzed for VOCs. Additional analyses of SVOCs and metals were also performed on a subset of these wells. Eight duplicate samples were collected from monitoring wells RIMW-4, RIMW-5, RIMW-8, RIMW-9, RIMW-15, RIMW-27, MW-117, and RIPZ-3. Where duplicate samples were collected, the average concentration of the parent and duplicate sample was used as a representative concentration for that location.

For the evaluation of potable water, data from all hydrologic units were used. However, for the vapor intrusion evaluation, groundwater data collected from "bedrock" wells were excluded. This dataset is referred to as "shallow groundwater" for the remainder of the characterization. It should be noted that three wells (BP-1B, MW-116, and PW-2A) were screened in both PWR and bedrock and therefore, the data from these wells were included in the both the potable water evaluation and the vapor intrusion evaluation.

Data excluded from the risk assessment includes samples associated with packer tests at RIMW-18 and RIMW-19. In addition, a sample collected from OB-13 was also excluded because it contained predominantly product and was analyzed on a per weight basis.

The list of the groundwater samples used in the risk assessment is provided in Appendix D tables. Well locations are shown in Figures 3-1, 3-4, and 3-5.

### 5.2.4 Quality Control

All data were subjected to the data validation process, as previously discussed in Section 4.7. Considering laboratory and field QA/QC, data employed in the risk characterization are considered of sufficient quality to support quantitative risk characterization.

## 5.3 Selection of COPCs

Tables presented in **Appendix H-1** summarize analytical data by medium and identify COPCs for the risk assessment. The range of detected concentrations, detection frequency, and the range of reporting limits presented in these tables were evaluated using sitewide datasets. These datasets are identified as current surface soil, future surface soil, subsurface soil, shallow (excluding bedrock) groundwater, and all groundwater data, as described above in Section 5.2.3.

Maximum detected concentrations of chemicals were compared, by medium, to risk-based screening levels to identify COPCs for each medium. Screening levels were taken from EPA Region 9 PRGs for residential soil and tap water (EPA 2004b), using a target cancer risk of  $10^{-6}$  (one in one million) and a target hazard quotient of 0.1. Chemicals were considered COPCs if their maximum detected concentration exceeded their respective screening levels. It should be noted that while Region IV EPA recommends the use of industrial PRGs for subsurface soil screening, residential PRGs were used based on the conservative assumption the property could be redeveloped for future residential use.

Risk-based screening levels were not available for the following chemicals: calcium, lead (groundwater only), magnesium, potassium, sodium, 2-chloronaphthalene, 2-methylnaphthalene, 2-nitrophenol, 3+4-methylphenol (soil only), 4-bromophenyl phenyl ether, 4 chlorophenyl phenyl ether, 4-nitrophenol, acenaphthylene, acetophenone, benzo(g,h,i)perylene, bis(2-chloroethoxy)methane, di-n-butylphthalate, p-chloro-m-cresol, phenanthrene, 1,1,2-trichloro-1,2,2-trifluoroethane, 1,2,3-trichlorobenzene, 2-hexanone, bromochloromethane, cis-1,3-dichloropropene, and trans-1,3-dichloropropene.

Calcium, magnesium, potassium, and sodium are essential metals and were not selected as COPCs. Di-n-butylphthalate and 1,1,2-trichloro-1,2,2-trifluoroethane were not selected as COPCs because no toxicity information is available for assessment.

Local ambient levels (background) of inorganic constituents were also considered in the selection of COPCs. Per Region IV guidance, twice the average background results were used to screen metals. Two background samples were available for this analysis (RI-BCK1 and RI-BCK2), and twice the average detected concentrations are presented in the COPC selection tables.

### 5.3.1 Exposure Units

To address potential soils exposures, a hot spot analysis was conducted and the site was divided into the following exposure units (EUs):

#### **Current Surface Soil (0 to 1 ft bgs):**

- All soil, excluding samples collected beneath structures and hot spots;
- Hot Spot 1 (sampling locations RISB-6, RISB-19, RISB-26 and RISB-46); and
- Hot Spot 2 (sampling location RIMW-6).

#### **Future Surface Soil (0 to 1 ft bgs)**

- All soil, excluding samples collected from hot spots;
- Hot Spot 1 (sampling locations RISB-6, RISB-19, RISB-26 and RISB-46);
- Hot Spot 2 (sampling location RIMW-6); and
- Hot Spot 3 (sampling location RISB-16).

It should be noted that Hot Spot 3 was only evaluated as a future exposure unit, as it is currently under a structure.

#### **Subsurface Soil**

- All soil, excluding samples collected from hot spots;
- Hot Spot RIMW-6;
- Hot Spot RISB-12;
- Hot Spot RISB-18;
- Hot Spot RISB-25; and
- Hot Spot RISB-64.

The results of the hot spot evaluation are presented in **Table 5-1**.

#### **Groundwater**

- Sitewide shallow groundwater; and
- Sitewide all groundwater.



## 5.4 Exposure Assessment

Exposure assessment involves the selection of receptor populations, exposure pathways for quantitative evaluation, and exposure point concentrations for selected COPCs for all relevant media. The methods and assumptions used to calculate exposure intake values for use in quantifying cancer risk and noncancer hazard are presented here. Environmental media that were addressed in exposure and risk/hazard calculations include surface soils (0 to 1 foot below ground surface or bgs), subsurface soils (all soil below ground surface), and groundwater. A site conceptual exposure model is presented in **Figure 5-1** and is summarized below.

### 5.4.1 Receptors

The following receptors and corresponding exposure pathways are relevant to the risk assessment and were addressed in either a quantitative or qualitative manner.

#### Known and Potential Current Receptors

**O&M Worker** – The O&M worker is an individual that currently operates and maintains the groundwater treatment system on the PSC site. His/her work involves running the treatment system from inside a building, administrative work from an office inside the building, and site maintenance outdoors (e.g., mowing the grass). The O&M worker is on site 3 days per week, 8 hours per day, and may be exposed to constituents in the surface soil through volatilization, fugitive dust generation, ingestion, and dermal contact. He/she may inhale constituents from volatilization of chemicals in groundwater to indoor air. It is assumed that he/she will not be exposed, via direct contact, to soils contained underneath the current concrete foundation of the existing buildings, or subsurface soils elsewhere on the site.

**Trespasser** – The trespasser is a hypothetical adolescent individual who could obtain access to the site without permission. This individual would be unsupervised and unaware of the potential exposure pathways of chemicals in the surface soil and groundwater. The trespasser may be on the site at anytime, but most likely not for long periods of time, and is assumed to trespass only in outside areas at the site with no potential for indoor exposure. The trespasser may potentially be exposed to constituents in the surface soil through volatilization, inhalation of fugitive dust, incidental ingestion, and dermal contact. It is assumed that he/she will not be exposed to soils, via direct contact, contained underneath the current concrete foundation of the existing buildings, or subsurface soils anywhere on the site. It is also assumed that since the current buildings on the site are either open air (i.e., no doors, no walls) or secured by an alarm, a trespasser will not be exposed to volatilization of chemicals in soil and groundwater to indoor air.

#### Potential Future Receptors

**Potential Future Excavation Worker** – Excavation workers are individuals who may be involved in the razing of buildings on the site and excavation or moving of surface and subsurface soil. Potential exposures associated with excavating soil on this site

include the inhalation of chemicals through volatilization and fugitive dust generation, and the incidental ingestion of and dermal contact with both surface and subsurface soils on the property. While working in a trench, a construction worker may also be exposed to constituents in groundwater that volatilize into ambient air.

**Potential Future Industrial Worker** – Industrial workers are individuals who may be working in a manufacturing or industrial facility, both indoors and out, on the site. He/she may inhale chemicals through volatilization and fugitive dust generation, and incidentally ingest and have dermal contact with soils on the property. Soil exposure may be to soils that are currently at the surface or with soils that are currently at the subsurface but may be brought to the surface during construction if a new facility is built on the site. The industrial worker may also inhale constituents from volatilization of chemicals in groundwater that migrate into indoor air. It is assumed that the industrial facility operating on the site may be using groundwater for drinking and hand washing.

**Potential Future Recreational User** – Recreational users are individuals who may perform activities such as baseball, walking or hiking, and picnicking. Potential exposures associated with performing recreational activities on this site include the inhalation of chemicals through volatilization and fugitive dust generation, and the ingestion of and dermal contact with surface soils on the property. Even if there is some type of clubhouse or restroom facilities on the property, exposure to constituents in groundwater through either ingestion of drinking water and via dermal absorption while washing hands or the inhalation of constituents from volatilization of chemicals in groundwater to indoor air would be insignificant based on low exposure potential. In addition, it is assumed that he/she will not be exposed to subsurface soils on the site.

**Potential Future Trespasser** - The trespasser is an adolescent individual who obtains access to site without permission. This individual would be unsupervised and unaware of the potential exposure pathways of chemicals in the surface soil and groundwater. He may inhale chemicals through volatilization and fugitive dust generation, and ingest and have dermal contact with surface soils on the property. It is assumed that the trespasser will not be able to access future buildings on the site and therefore, will not be exposed to volatilization of chemicals in soil and groundwater to indoor air. It is also assumed that a trespasser will not be exposed to subsurface soils anywhere on the site.

**Potential Future Residents** – Potential future residential receptors are assumed to have their primary place of residence on the site. Potential exposures associated with living on this site include the inhalation of contaminants through volatilization, incidental ingestion of and dermal contact with soils, and inhalation of fugitive dust generated from soils on the property. Soil exposure may be to soils that are currently at the surface or with soils that are currently at the subsurface that may be brought to the surface during construction of a new home with a basement.

In the event that residential receptors use groundwater at the site, they have potential to ingest groundwater contaminants through drinking water and experience dermal contact through hand washing. Other potential exposures include both dermal contact and inhalation of volatile groundwater contaminants while showering (relating to dermal absorption and inhalation of volatiles in shower air, but assessed as being equivalent to ingestion of 2 L of water per day, consistent with EPA Region 4 guidance (EPA 2000)).

## 5.4.2 Exposure Scenarios

Appendix H-2 summarizes the exposure factors used in exposure intake and risk/hazard calculations for each of the receptors at the site. Each exposure scenario is discussed below.

### 5.4.2.1 Current O&M Worker Exposure Assumptions

The current O&M workers at the site are assumed to be exposed to surface soil via incidental ingestion, dermal contact, inhalation of soil vapor and inhalation of fugitive dust, and to groundwater via inhalation of vapors in indoor air.

An incidental ingestion rate for soil for an O&M worker is assumed to be 50 mg/day (EPA 1997a). For dermal contact with soil, the O&M worker is assumed to wear a short-sleeved shirt, pants, and shoes; therefore, the exposed skin surface is limited to the face, forearms and hands. The exposed skin surface area for an O&M worker is 3,300 cm<sup>2</sup>, the average of the 50<sup>th</sup> percentile for adult males and females (EPA 2002). A dermal adherence factor of 0.2 mg/cm<sup>2</sup> per event was assumed for the O&M worker (EPA 2004a).

An inhalation rate of soil vapors of 1 m<sup>3</sup>/hour was assumed for the O&M worker (EPA 1997a). O&M workers are assumed to be exposed to soil at the PSC site for 250 days/year over 25 years (EPA 2002).

A life expectancy of 25,550 days (70 years) (EPA 1989) was used for outdoor workers as the averaging time for exposure to carcinogenic contaminants. The averaging time for noncarcinogenic effects is equal to the exposure duration, or 9,125 days (25 years) for this scenario. A body weight of 70 kg for adults was used (EPA 1991, 2002) based on the mean 50<sup>th</sup> percentile body weight for the age group.

### 5.4.2.2 Trespasser / Recreational Visitor Exposure Assumptions

Current and future trespassers and future recreational visitors at the site are assumed to be exposed to surface soil during recreational activities, such as playing, via incidental ingestion, dermal contact, and inhalation of soil dust and vapors.

A teen/adolescent (ages 6 to 18 years old) was evaluated for both carcinogenic and noncarcinogenic hazards. For the assessment of soil for teen/adolescent recreational visitors/trespassers, an incidental ingestion rate for soil was assumed to be 100 mg/day (EPA 1997a). For dermal contact with soil, the teen/adolescent recreational

visitors/trespasser was assumed to wear a short-sleeved shirt and shorts; therefore, the exposed skin surface is limited to the face, forearms, hands, lower legs and feet. The exposed skin surface area for children is 7,605 square centimeters (cm<sup>2</sup>), (mean surface area for children 6-16 (head, arms, hands, legs); (EPA 1997a). A dermal adherence factor of 0.2 mg/cm<sup>2</sup> per event was also employed (EPA 2004a).

Teen/adolescent recreational visitors/trespassers were assumed to be exposed for 144 days per year. One hundred and forty-four days is the equivalent of about 12 days per month, year round (Professional Judgment). Exposure is expected to occur over 12 years (Professional Judgment). The averaging time for noncarcinogenic effects is equal to the exposure duration, 4,380 days. A body weight of 42 kg was employed (EPA 2007a).

For the assessment of cancer risks, a 12 year exposure scenario was employed. Mutagenic compounds, such as 1,2-DCA, were assessed following the approach in EPA's *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (EPA, 2005a). The default risk approach was modified for mutagenic compounds to incorporate differential risk of early lifestage exposure.

#### 5.4.2.3 Future Excavation Worker Exposure Assumptions

Future excavation workers are assumed to be exposed to surface and subsurface soils for the duration of a single project involving excavation. If multiple non-concurrent construction projects are anticipated, different workers are assumed to be employed for each project. Activities for this receptor typically involve substantial, though short-term, exposures to soils via incidental ingestion, dermal contact, inhalation of fugitive dust and vapors, and the inhalation of vapors from shallow groundwater to the ambient air.

A soil incidental ingestion rate for a construction worker is assumed to be 330 mg/day (EPA 2002), appropriate for short-term but intense contact with soil. For dermal contact with soil, construction workers are assumed to wear a short-sleeved shirts, pants, and shoes; therefore, the exposed skin surface is limited to the head, hands and forearms. The exposed skin surface area for construction workers is 3,300 cm<sup>2</sup>, the average of the 50<sup>th</sup> percentile for adult males and females (EPA 2002). A dermal adherence factor of 0.2 mg/cm<sup>2</sup> per event was assumed (EPA 2004a).

An inhalation rate of 20 m<sup>3</sup>/day was assumed for the construction worker for the inhalation of soil and groundwater vapors and inhalation of fugitive dust (EPA 2004a). The derivation of volatilization factors for excavation worker groundwater inhalation risks are included in the applicable risk calculations. The frequency with which construction workers were assumed to be exposed to soil at the site was 250 days with an exposure duration of one year.

A life expectancy of 25,550 days (70 years) (EPA 2004a) was used for excavation workers as the averaging time for exposure to carcinogenic contaminants. The

averaging time for noncarcinogenic effects is equal to the subchronic exposure duration, or 365 days. A body weight of 70 kg for adults was employed (EPA 1991a, 2002a) based on the mean 50<sup>th</sup> percentile body weight for the age group.

#### **5.4.2.4 Future Industrial Worker Exposure Assumptions**

Future industrial workers at the site are assumed to be exposed to surface soil via incidental ingestion, dermal contact, inhalation of soil vapor and inhalation of fugitive dust. In addition, it is assumed that they would be exposed to groundwater through ingestion and dermal contact through future potable use of groundwater as well as through inhalation of vapors in indoor air.

An incidental ingestion rate for soil for an industrial worker is assumed to be 50 mg/day (EPA 1997a). For dermal contact with soil, an outdoor worker is assumed to wear a short-sleeved shirt, pants, and shoes; therefore, the exposed skin surface is limited to the face, forearms and hands. The exposed skin surface area for an outdoor worker is 3,300 cm<sup>2</sup>, the average of the 50<sup>th</sup> percentile for adult males and females (EPA 2002). A dermal adherence factor of 0.2 mg/cm<sup>2</sup> per event was assumed for the industrial worker (EPA 2004a).

An inhalation rate of soil vapors of 1 m<sup>3</sup>/hour was assumed for the industrial worker (EPA 1997a). Outdoor industrial workers are assumed to be exposed to soil at the site for 250 days/year over 25 years (EPA, 2002).

A life expectancy of 25,550 days (70 years) (EPA 2004a) was used for industrial workers as the averaging time for exposure to carcinogenic contaminants. The averaging time for noncarcinogenic effects is equal to the exposure duration, or 9,125 days (25 years) for this scenario. A body weight of 70 kg for adults was used (EPA 1991, 2002) based on the mean 50<sup>th</sup> percentile body weight for the age group.

#### **5.4.2.5 Future Residential Exposure Assumptions**

Future residents are assumed to be exposed to soil during recreational activities such as playing or gardening via incidental ingestion, dermal contact, inhalation of soil vapors and dust. If the home is built on a slab, it is assumed that the residents would only have exposure to surface soils; however, if a home is constructed with a basement, then exposure to subsurface soils would be possible. It is also assumed that future residents would be exposed to groundwater through ingestion and dermal contact and inhalation of vapors in indoor air.

For noncarcinogenic hazards, children receive the highest daily exposures because of lower body weight and higher contact rates, particularly for incidental soil ingestion. Only young children, therefore, are quantitatively assessed for exposure to noncarcinogens.

Cancer risks for nonmutagenic chemicals were evaluated employing a 30-year cumulative scenario that calculated risks for children and adults ages 1-31 years old.

Cancer risks for mutagenic chemicals were evaluated employing a 30-year cumulative scenario that calculated risks for four age groups: children ages 0-2 years old; children 2-6 years old; older children 6-15 years old; and adults ages 15-30 years old. Cancer risks are evaluated over long time periods because cancer risks are proportional to cumulative exposure.

For the assessment soil, an incidental ingestion rate for soil was assumed to be 200 mg/day (EPA 2007a) for young children. The soil ingestion rate for adults was assumed to be 50 mg/day (EPA, 1997a). For dermal contact with soil, the child resident was assumed to wear a short-sleeved shirt and shorts; therefore, the exposed skin surface is limited to the face, forearms, hands, lower legs and feet. The exposed skin surface area for children is 2,800 square centimeters (cm<sup>2</sup>), the average of the 50<sup>th</sup> percentile for males and females between the ages of one and six (EPA 2002). For adult dermal contact with soil, the exposed skin surface area was calculated based on the average of the 50<sup>th</sup> percentile for males and females assuming exposure to the face, forearms, hands and lower legs. A dermal adherence factor of 0.2 mg/cm<sup>2</sup> per event was assumed (EPA 2004a) for both children and adults.

For groundwater related noncancer hazards, an ingestion rate for water was assumed to be 2 L/day for adults and 1 L/day for young children (EPA 2007a). For dermal contact and inhalation of vapors while showering, the risk was assumed to be equivalent to ingestion risk (EPA 2007a).

Child and adult residents were assumed to be exposed for 350 days per year. The exposure duration was six years (EPA 2002) for young children and 30 years for child/adult carcinogenic exposure. The averaging time for noncarcinogenic effects was equal to the exposure duration, 2,190 days (six years). Averaging time for carcinogenic effects was over a life expectancy of 25,550 days (70 years). A body weight of 15 kg was employed for young children and 70 kg for child/adults (EPA 2002).

### **5.4.3 Exposure Point Concentrations**

An EPC is an estimate of the concentration of a COPC at points of exposure for different groups of receptors. This concentration term is calculated as the lower of the maximum detected concentration or the 95 percent upper confidence limit (UCL) of the arithmetic mean. This approach provides a conservative (protective) estimate of average COPC concentrations to account for uncertainties in the risk assessment dataset (EPA 1989). EPCs may be estimated by (1) using environmental data alone, or (2) using a combination of environmental data and environmental fate and transport models. In this assessment, EPCs for soil and groundwater were estimated using environmental data only.

#### **5.4.3.1 Calculation of Exposure Point Concentrations**

EPCs represent concentrations of COPCs to which receptors may be exposed. EPCs serve as input into risk calculations and are derived for all COPCs for each area of

concern. EPCs can be used, along with appropriate exposure assumptions, to reflect a range of potential exposures (average, reasonable upper range, worst case). Most often where data quantity allow, single EPCs are used to represent possible exposure concentrations. Typically, EPCs are estimated as the lower concentration of the maximum detected concentration or the upper one-sided 95% confidence limit of the arithmetic mean concentration (95% UCL) to help ensure the actual average concentration is not underestimated. The choice of the arithmetic mean as an appropriate statistic for characterizing exposure at an exposure point is based on the assumption of random exposure within the exposure area (EPA 1989).

For each chemical with 10 or more samples, a 95%UCL on the arithmetic mean concentration was calculated and compared to the maximum detected concentration for that chemical. The lower value of the UCL and the maximum detected value was then selected as the EPC, as recommended by EPA (EPA 1992). For chemicals with less than 10 samples, the maximum detected concentration was used.

Different statistical methods can be used to estimate the 95% UCL of a data set, depending upon the data distribution. Therefore, two key steps are required to estimate the 95% UCL of a data set:

- Determine the distribution of the data (i.e., normal, lognormal, gamma or other).
- Compute the 95% UCL using the appropriate procedure for the data distribution.

In this assessment, both steps were performed with the ProUCL statistical software Version 4.0 developed for EPA (2007b). The ProUCL program contains rigorous parametric and nonparametric (including bootstrap methods) statistical methods (instead of simple *ad hoc* or substitution methods) that can be used on full data sets without nondetects (NDs) and on data sets with below reporting limit (RL) or ND observations.

ProUCL computes the 95%UCL using state-of-the-art parametric and nonparametric methods that can be used on full-uncensored data sets without NDs and also on data sets with below RL observations. ProUCL also provides goodness-of-fit tests for normal, lognormal, and gamma distributions where the ND values can be extrapolated (estimated) based upon normal regression on statistics (ROS), gamma ROS, and lognormal ROS (robust ROS) methods.

For highly censored datasets (i.e., if the percentage of NDs within a data set is greater than 80%), the maximum RL for ND data is compared to the maximum detected concentration. If the maximum RL for the NDs is greater or equal to the maximum concentration, then all NDs with RLs greater than the maximum concentration are excluded from the data set. Otherwise, the RL is used as the substitute for ND values.

Using the data set generated from the ND evaluation, percentiles of the data set are determined, and the 95<sup>th</sup> percentile is selected as the EPC.

Tables presented in **Appendix H-3** provide EPC summaries for each COPC in each medium and identify the statistical procedure used to calculate UCLs. ProUCL Version 4.0 output tables are provided in **Appendix H-4**.

#### **5.4.4 Modeling Techniques Used to Estimate EPCs**

Modeling was used to estimate exposure point concentrations and/or risk estimates that involve the transfer of contaminants from one medium to another: soil particulates released into ambient air, contaminants in groundwater that volatilize into ambient air in a trench, and contaminants from groundwater that volatilize into indoor air.

##### **Soil Particulates**

In order to evaluate the inhalation of fugitive dust for the various surface and subsurface data sets, a particulate emission factor (PEF) was derived employing soil modeling equations provided in *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (EPA 2002). A standard PEF is developed based on physical features of the soil and site that affect the resuspension of soil particulates as well as local climatic conditions that influence dispersion of particulates. EPA default values were used in the calculation of the PEF with the exception the Q/C variable that was adjusted for a 50 acre site. The resulting PEF factor for the site was calculated as 6.8E+08. Fugitive dust EPCs were calculated by dividing soil concentrations by the PEF.

##### **Vapors in Excavation**

In order to evaluate the inhalation of vapors from groundwater in a trench for construction workers, a volatilization factor (VF) was calculated for each shallow groundwater COPC. The equations used to estimate the groundwater-to-air VF for each COPC are presented Appendix H-5. The equation is a simple vadose zone model used to estimate volatilization of vapors from contaminated groundwater in a trench and dispersion of the contaminants into ambient trench air. Chemical specific properties for each chemical such as Henry's Law Constant, carbon-to-water sorption coefficient (Koc), diffusion coefficient in air and diffusion coefficient in water used in the calculations and were obtained from *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings* (EPA 2004c). The VF for each COPC was multiplied the concentration in shallow groundwater to obtain the construction worker EPC in ambient air.

##### **Vapor Intrusion Modeling**

The Johnson and Ettinger model for subsurface vapor intrusion into buildings was used to evaluate potential worker and residential inhalation exposures to VOCs in indoor air originating from shallow groundwater contamination.



EPCs for the shallow groundwater plume were inserted into the model to yield risk/hazard estimates for a current O&M worker, future industrial worker and future resident. The model defaults were used for all parameters except the following site-specific parameters:

- Depth below grade to water table – 15 feet
- Depth below grade to bottom of enclosed floor space – 200 cm
- Depth below grade to top of contamination – 200 cm
- Soil type directly above water table – typically clayey silt, silt and sandy silt and silty clay (Silt Loam specified in the model runs)
- Average soil/groundwater temperature – 61° F (16° C)

## 5.5 Toxicity Assessment

A toxicity assessment identifies chemical specific criteria that reflect the intrinsic toxicity of COPCs to humans. These criteria are used, along with estimates of exposure, to estimate potential cancer risks and noncancer hazards for receptors identified in Section 5.4. Risk and hazard estimates are provided in Section 5.7.

Toxicity criteria used in this risk assessment were obtained from a variety of sources according to a hierarchy established in the Office of Solid Waste and Emergency Response (OSWER) Directive 9285.7-53 (EPA 2003). The toxicity value hierarchy is as follows:

- Tier 1—EPA's Integrated Risk Information System (IRIS) (EPA 2007c).
- Tier 2—EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs): The Office of Research and Development/NCEA/Superfund Health Risk Technical Support Center (STSC) develops PPRTVs on a chemical-specific basis when requested by EPA's Superfund program (EPA 2007d).
- Tier 3—Other Toxicity Values: Tier 3 includes additional EPA and non-EPA sources of toxicity information. Priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer-reviewed.

### 5.5.1 Health Effects Criteria for Non-carcinogens

For chemicals that exhibit non-carcinogenic (e.g., systemic) effects, organisms have repair and detoxification capabilities that must be exceeded by some critical concentration (threshold) before the health effect is manifested. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without an appreciable hazard of adverse effects.

Health criteria for chemicals exhibiting non-carcinogenic effects for use in risk assessment are generally EPA-derived reference doses (RfDs) and reference concentrations (RfCs). The RfD or RfC is an estimate of average daily exposure to an individual (including sensitive individuals) that is likely to be without appreciable risk of deleterious effects during a lifetime. The RfD is expressed in units of milligram (mg) chemical per kilogram (kg) body weight per day (mg/kg-day); while the RfC is expressed in units of mg chemical per cubic meter (m<sup>3</sup>) of air (mg/m<sup>3</sup>). RfDs and RfCs are usually derived either from human studies involving work-place exposures or from animal studies, and are adjusted using uncertainty factors to ensure that they are unlikely to underestimate the potential for adverse non-carcinogenic effects to occur.

Uncertainty factors reflect scientific judgment regarding the various types of data used to estimate the RfD/RfC and generally consist of multiples of factors ranging from 1 to 10. For example, a factor of 10 may be introduced to account for possible differences in response between humans and animals in prolonged exposure studies. Other factors may be used to account for variation in susceptibility among individuals in the human population, use of data from a study with less-than-lifetime exposure, and/or use of data from a study that did not identify a no-observed-adverse-effect level (NOAEL).

RfDs and RfCs provide benchmarks against which estimated doses (i.e., those projected from human exposures to various environmental conditions) are compared. Doses that are significantly higher than the RfD/RfC may indicate an increased potential of hazard from the exposure, while doses that are less than the RfD/RfC are not likely to be associated with adverse health effects. It should be noted that an exceedance of the RfD/RfC does not provide an estimate of the likelihood of adverse effects. It only reflects an increased potential hazard for noncancer health effects.

### 5.5.2 Health Effects Criteria for Potential Carcinogens

For chemicals that exhibit carcinogenic effects, EPA recognizes that more than one molecular event must occur to transform a cell from its normal state into a cancerous one. However, EPA regulates carcinogens using a non-threshold concept that assumes that a single change to the genome of a cell can initiate the carcinogenesis process. This non-threshold theory of carcinogenesis therefore assumes that any level of exposure to a carcinogen is associated with some finite possibility of causing cancer. Generally, regulatory agencies assume that the non-threshold hypothesis for carcinogens holds regardless of information concerning mechanisms of carcinogenic action for the chemical.

The carcinogenic potential of a chemical is expressed as a cancer slope factor (CSF) [in units of (mg/kg body weight-day)<sup>-1</sup>], which estimates the risk of cancer per unit dose. When a slope factor is multiplied by an estimate of lifetime average daily dose (ADD) of a potential carcinogen (in mg/kg body weight-day), the result is an estimate of the lifetime excess cancer risk associated with exposure at that dose. EPA develops CSFs in a conservative manner, and risk estimates using slope factors are considered to be

upper bound estimates of those possible. Risks estimated using slope factors are considered unlikely to underestimate actual risks and may substantially overestimate risks for a given exposure.

Excess lifetime cancer risks (ELCRs) are generally expressed in scientific notation and are probabilities. An ELCR of  $1 \times 10^{-6}$  (one in one million), for example, represents the incremental probability that an individual will develop cancer as a result of exposure to a carcinogenic chemical over a 70-year lifetime under specified exposure conditions. In addition, CSFs are developed for a specific route of exposure, either oral or inhalation, and ELCRs are estimated separately for these two routes of exposure.

In practice, CSF estimates are derived from the results of human epidemiology studies or chronic animal bioassays. The animal studies are conducted for a range of doses, including a high dose, in order to detect possible adverse effects. Since humans are expected to be exposed at lower doses than those used in animal studies, the data are adjusted via mathematical models. The data from animal studies are typically fitted to the linearized multistage model to obtain a dose-response curve. EPA evaluates a range of possible models based on the available data before conducting the extrapolation. The most appropriate model to reflect the data is selected based on an analysis of the data set.

The 95% UCL slope of the dose-response curve, subject to various adjustments and an inter-species scaling factor, is applied to derive the health protective CSF estimate for humans. Dose-response data from human epidemiological studies are fitted to dose-time-response curves. These models provide rough, but reasonable, estimates of the upper limits on lifetime risk. CSF estimates based on human epidemiological data are also derived using health protective assumptions and, as such, they too are considered unlikely to underestimate risks. Therefore, while actual risks associated with exposures to potential carcinogens are unlikely to be higher than the risks calculated using a slope factor estimate, they could be considerably lower.

In addition, there are varying degrees of confidence in the weight of evidence for carcinogenicity of a given chemical. EPA (1989) has proposed a system for characterizing the overall weight of evidence based on the availability of animal, human, and other supportive data. The weight-of-evidence classification is an attempt to determine the likelihood that an agent is a human carcinogen and thus qualitatively affects the estimation of potential health risks.

Three major factors are considered in characterizing the overall weight of evidence for human carcinogenicity: (1) the availability and quality of evidence from human studies, (2) the availability and quality of evidence from animal studies, and (3) other supportive information which is assessed to determine whether the overall weight of evidence should be modified. Carcinogens have often been grouped into the following five categories based on strength of this evidence:

- human Carcinogen: There is at least sufficient evidence from human epidemiological studies to support a causal association between an agent and cancer;
- probable Human Carcinogen: There is at least limited evidence from epidemiological studies of carcinogenicity in humans (Group B1) or, in the absence of adequate data in humans, there is sufficient evidence of carcinogenicity in animals (Group B2);
- possible Human Carcinogen: There is inadequate evidence of carcinogenicity in humans;
- not Classified: There is inadequate data or no existing data for the chemical; and
- no Evidence of Carcinogenicity in Humans: There is no evidence for carcinogenicity in at least two adequate animal tests in different species or in both epidemiological and animal studies.

The EPA 2005 Cancer Guidelines (EPA 2005b) update previous versions and suggest a slightly different approach to categorizing carcinogens. These guidelines emphasize the value of understanding the biological changes a chemical can cause and how these changes might lead to the development of cancer. They also discuss methods to evaluate and use such information, including information about an agent's postulated *mode-of-action*. Mode-of-action data, when available and of sufficient quality, may be useful in drawing conclusions about the potency of an agent, its potential effects at low doses, whether findings in animals are relevant to humans, and which populations or life stages may be particularly susceptible. In the absence of mode-of-action information, default options are available to allow the risk assessment to proceed.

The 2005 Cancer Guidelines (EPA 2005b) recommend an agent's human carcinogenic potential be described in a *weight-of-evidence narrative* rather than the previously identified categories. The narrative summarizes the full range of available evidence and describes any conditions associated with conclusions about an agent's hazard potential. For example, the narrative may explain that an agent appears to be carcinogenic by some routes of exposure but not others (e.g., by inhalation but not ingestion). Similarly, a hazard may be attributed to exposures during sensitive life stages of development but not at other times. The narrative also summarizes uncertainties and key default options that have been invoked.

The following five standard hazard descriptors are still used in the newest guidelines:

- carcinogenic to humans;
- likely to be carcinogenic to humans;

- suggestive evidence of carcinogenic potential;
- inadequate information to assess carcinogenic potential; and
- not likely to be carcinogenic to humans.

However, requirements for in-depth analysis of "mode-of-action data" and other modifying information preclude the use of these descriptors to place chemicals into categories as was done previously.

The 2005 Cancer Guidelines (EPA 2005b) also include Supplemental Guidance (EPA 2005a) on the evaluation of early lifetime exposures. For example, where data are available that indicate a chemical is mutagenic, the Supplemental Guidance recommends either developing age-specific slope factors or generic age dependent adjustment factors. Application of the supplemental guidance for this risk assessment is explained in text of the exposure assessment (Section 5.4), and, where appropriate, was used to adjust cancer risk estimates.

### 5.5.3 Toxicological Assessment

**Tables 5-2** and **5-3** summarize the chronic RfDs and RfCs used to estimate non-carcinogenic effects for the COPCs, and **Tables 5-4** and **5-5** summarize the CSFs used to estimate cancer risks for the COPCs. These criteria are the most current data, obtained from the 2007 on-line version of IRIS and current NCEA recommendations.

## 5.6 Risk Characterization

In this section of the risk assessment, human health risks potentially associated with complete human exposure pathways identified in Section 5.4 are characterized, integrating toxicity and exposure assessments into quantitative expressions of carcinogenic risk and noncancer hazards. Potential risks due to exposures to soil and groundwater via incidental ingestion, dermal contact, and inhalation were quantitatively evaluated. Cancer risk and noncancer hazard calculations for all COPCs for all scenarios are summarized and presented in **Appendix H-5**. Total cancer risk and noncancer hazard for each dataset and receptor are summarized in **Table 5-6**.

The potential for noncancer health hazards was evaluated by comparing ADDs with reference doses applicable for chronic (long-term) and subchronic (shorter-term) exposure. This ratio of exposure to toxicity is referred to as a hazard quotient (HQ). A hazard index (HI) is the sum of HQs from individual chemicals. An RfD or RfC defines an ADD below which it is unlikely even for sensitive populations to experience adverse health effects. Thus, if an HI exceeds unity (1), the ADD is higher than a "safe" exposure level and some concern for potential noncancer effects exists. An HI is not, however, an expression of probability of noncancer effects occurring. Generally, the greater the HI above unity, the greater the level of concern. HQs are typically only added together to estimate HIs for chemicals that affect the same target organ(s) or tissue(s).

Cancer risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. The upper-bound ELCR is estimated by multiplying the lifetime average daily dose (LADD) by an appropriate CSF. ELCRs are generally expressed in scientific notation as incremental probabilities. An ELCR of  $1 \times 10^{-6}$  (1 in 1,000,000), for example, represents the incremental probability that an individual will develop cancer as a result of exposure to a carcinogenic chemical over a 70-year lifetime under specified exposure conditions. This increment is in addition to the risk of developing cancer from causes unrelated to the exposure. Typical cancer rates in the United States are in the range of 1 in 4 to 1 in 2.

Generally, EPA uses a target cancer risk range of  $10^{-6}$  to  $10^{-4}$  (1 in 1,000,000 to 1 in 10,000) to evaluate the need for remediation or mitigation at a site (EPA 1991b). Cancer risks below 1 in 1,000,000 are typically assumed to be *de minimis* and would require no remediation or mitigation. Decisions on whether to remediate or mitigate risk for risks that fall in this range are made on a site-specific basis. Risks that exceed 1 in 10,000 often require remediation and/or mitigation; however, no "bright line" has been established at the upper end of the risk range, and, again, risk management decisions are made on a site-by-site basis. The South Carolina Department of Health and Environmental Control's policy is to use  $10^{-6}$  as the basis for whether a risk is acceptable or unacceptable.

Estimates of cancer risk and hazard indices are compared to the above targets to put the magnitude of cancer risks and noncancer hazards into perspective for the risk manager.

### 5.6.1 Results of Risk Calculations

Potential risks were estimated for each area of concern for applicable receptors. In some instances, the site was considered as a whole (single exposure unit). Exposure to all groundwater was considered a single exposure unit for future residents and industrial workers, employing EPCs from the most impacted area of the plume. Cancer risks and noncancer health hazards for each receptor in each area under current/future, current, and future land use conditions are discussed in the following sections. Estimates of total cancer and noncancer hazards by exposure route and medium are summarized by receptor in Table 5-6. Risk and Hazard calculations and summaries by receptor and chemical can be found in Appendix H-5.

### 5.6.2 Risk and Hazard Results

#### 5.6.2.1 Surface Soil (Excluding Hot Spots and Beneath Structures) and Groundwater

##### *Current O&M Worker*

The total estimated cancer risk for current O&M workers ( $9 \times 10^{-5}$ ) is within EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to inhalation of volatiles in indoor air from shallow groundwater (99%). Trichloroethene

(TCE), 1,2-dichloroethane (1,2-DCA), tetrachloroethene (PCE), and vinyl chloride (VC) are the primary contributors to risk associated with groundwater exposure.

The total HI for current O&M workers (0.8) is below EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to inhalation of volatiles in indoor air from shallow groundwater (45%), ingestion of surface soil (33%) and dermal contact with surface soil (22%). PCE and xylenes are the primary contributors to groundwater exposure hazard, and thallium is the primary contributor to soil exposure hazards.

#### ***Current Teen/Adolescent Trespasser***

The total estimated cancer risk for current trespassers ( $1 \times 10^{-6}$ ) meets the *de minimus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to ingestion of surface soil (67%) and dermal contact with surface soil (32%). Arsenic is the primary contributor to risk associated with soil exposures.

The total HI for current trespassers (1) meets EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to ingestion of surface soil (57%) and dermal contact with surface soil (43%). Thallium is the primary contributor to soil exposure hazards.

### **5.6.2.2 Surface Soil (Hot Spot 1) and Groundwater**

#### ***Current O&M Worker***

The total estimated cancer risk for current O&M workers ( $9 \times 10^{-5}$ ) is within EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to inhalation of volatiles in indoor air from shallow groundwater (99%). TCE, 1,2-DCA, PCE, and VC are the primary contributors to risk associated with groundwater exposure.

The total HI for current O&M workers (0.8) is below EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to inhalation of volatiles in indoor air from shallow groundwater (41%), ingestion of surface soil (35%) and dermal contact with surface soil (23%). PCE and xylenes are the primary contributors to groundwater exposure hazard, and thallium is the primary contributor to soil exposure hazards.

#### ***Future Industrial Worker***

The total estimated cancer risk for future industrial workers ( $9 \times 10^{-3}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. PCE, 1,2-DCA, and TCE are the primary contributors to risk associated with groundwater exposure.

The total HI for future industrial workers (63) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater.

Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE, cis-1,2-dichloroethene (cis-1,2-DCE), PCE, and toluene are the primary contributors to risk associated with groundwater exposure.

#### ***Future Residents***

The total estimated cancer risk for future residents ( $3 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the risk. TCE, 1,2-DCA, PCE, VC, and benzene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure risk is within EPA's target risk range, with arsenic and PCE as the primary contributors.

The total HI for future residents (409) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 48% of the hazard. TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall hazard, it should be noted that when assessed by only this medium, hazard exceeds the noncancer threshold of 1. Thallium and vanadium are the primary contributors to risk associated with soil exposures.

#### ***Current/Future Teen/Adolescent Trespasser***

The total estimated cancer risk for current/future trespassers ( $1 \times 10^{-6}$ ) meets the *de minimus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to ingestion of surface soil (62%) and dermal contact with surface soil (32%). Arsenic and PCE are the primary contributors to risk.

The total HI for current trespassers (2) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to ingestion of surface soil (57%) and dermal contact with surface soil (43%). Thallium is the primary contributor to soil exposure hazards.



### 5.6.2.3 Surface Soil (Hot Spot 2) and Groundwater

#### *Current O&M Worker*

The total estimated cancer risk for current O&M workers ( $9 \times 10^{-5}$ ) is within EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to inhalation of volatiles in indoor air from shallow groundwater (100%). TCE, 1,2-DCA, PCE, and VC are the primary contributors to risk associated with groundwater exposure.

The total HI for current O&M workers (0.3) is below EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to inhalation of volatiles in indoor air from shallow groundwater (100%). PCE and xylenes are the primary contributors to groundwater exposure hazard.

#### *Future Industrial Worker*

The total estimated cancer risk for future industrial workers ( $9 \times 10^{-3}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. PCE, 1,2-DCA, and TCE are the primary contributors to risk associated with groundwater exposure.

The total HI for future industrial workers (62) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the hazard. TCE, cis-1,2-DCE, PCE, and toluene are the primary contributors to risk associated with groundwater exposure.

#### *Future Residents*

The total estimated cancer risk for future residents ( $3 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the risk. TCE, 1,2-DCA, PCE, VC, and benzene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater does not significantly impact overall risk, it should be noted that when this medium is assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors.

The total HI for future residents (395) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these

pathways contributed 50% of the hazard. TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure.

***Current/Future Teen/Adolescent Trespasser***

The total estimated cancer risk for current/future trespassers ( $2 \times 10^{-7}$ ) is below EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to ingestion of surface soil (46%), dermal contact with surface soil (39%) and inhalation of fugitive dust and vapors from surface soil (15%). Arsenic and PCE are the primary contributors to risk.

The total HI for current trespassers (0.0007) is well below EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to inhalation of fugitive dust and vapors from surface soil (84%) and ingestion of surface soil (10%).

**5.6.2.4 Surface Soil (Hot Spot 3) and Groundwater**

***Future Teen/Adolescent Trespasser***

The total estimated cancer risk for future trespassers ( $1 \times 10^{-6}$ ) meets the *de minimus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to ingestion of surface soil (61%) and dermal contact with surface soil (32%). Arsenic and PCE are the primary contributors to risk associated with soil exposures.

The total HI for future trespassers (4) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to ingestion of surface soil (57%) and dermal contact with surface soil (43%). Thallium is the primary contributor to soil exposure hazards.

***Future Industrial Worker***

The total estimated cancer risk for future industrial workers ( $9 \times 10^{-3}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. PCE, 1,2-DCA and TCE are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater does not significantly impact overall risk, it should be noted that when this medium is assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, and VC as primary contributors.

The total HI for future industrial workers (63) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE and cis-1,2-DCE are the primary

contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall risk, it should be noted that when this medium is assessed individually, soil exposure hazard exceeds EPA's noncancer threshold, with thallium as the primary contributor.

#### ***Future Residents***

The total estimated cancer risk for future residents ( $3 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the risk. TCE, 1,2-DCA, PCE, VC, and benzene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure risk is within EPA's target risk range, with arsenic and PCE as the primary contributors.

The total HI for future residents (419) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 47% of the hazard. TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall risk, it should be noted that when this medium is assessed individually, soil exposure hazard exceeds EPA's noncancer threshold, with thallium, manganese, and iron as the primary contributors.

#### **5.6.2.5 Surface Soil (Excluding Hot Spots) and Groundwater**

##### ***Future Industrial Worker***

The total estimated cancer risk for future industrial workers ( $9 \times 10^{-3}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. PCE, 1,2-DCA, and TCE are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater does not significantly impact overall risk, it should be noted that when this medium is assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, and VC as primary contributors.

The total HI for future industrial workers (62) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE, cis-1,2-DCE, PCE, and toluene are the primary contributors to risk associated with groundwater exposure.

#### ***Future Teen/Adolescent Trespasser***

The total estimated cancer risk for future trespassers ( $1 \times 10^{-6}$ ) meets the *de minimus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to ingestion of surface soil (62%) and dermal contact with surface soil (32%). Arsenic is the primary contributor to risk associated with soil exposures.

The total HI for future trespassers (1) meets EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to ingestion of surface soil (57%) and dermal contact with surface soil (43%). Thallium is the primary contributor to soil exposure hazards.

#### ***Future Residents***

The total estimated cancer risk for future residents ( $3 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the risk. 1,2-DCA, TCE, and VC are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall risk, it should be noted that when assessed by only this medium, risk is with EPA's target risk range. Arsenic and 1,2-DCA are the primary contributors to risk associated with soil exposures.

The total HI for future residents (408) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 48% of the hazard. TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall hazard, it should be noted that when assessed by only this medium, hazard exceeds the noncancer threshold of 1. Thallium and vanadium are the primary contributors to risk associated with soil exposures.

### **5.6.2.6 Subsurface Soil (Excluding Hot Spots) and Groundwater**

#### ***Future Industrial Worker***

The total estimated cancer risk for future industrial workers ( $9 \times 10^{-3}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to

potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. PCE, 1,2-DCA, and TCE are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater does not significantly impact overall risk, it should be noted that when this medium is assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, and VC as primary contributors.

The total HI for future industrial workers (67) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 46% of the hazard. TCE, cis-1,2-DCE, PCE, and toluene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall risk, it should be noted that when this medium is assessed individually, soil exposure hazard exceeds EPA's noncancer threshold, with vanadium as the primary contributor.

#### ***Future Excavation Worker***

The total estimated cancer risk for future excavation workers ( $3 \times 10^{-7}$ ) is below EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to inhalation of ambient air from shallow groundwater (42%), followed by ingestion of surface soil (45%) and inhalation of fugitive dust and vapors from soil (11%).

The total HI for future excavation workers (5) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to ingestion of soil (90%). Vanadium and thallium are the primary contributors to subsurface soil exposure hazard.

#### ***Future Residents***

The total estimated cancer risk for future residents ( $3 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the risk. TCE, 1,2-DCA, PCE, VC, and benzene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure risk is within EPA's target risk range, with arsenic, 1,2-DCA, and TCE as the primary contributors.

The total HI for future residents (486) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 41% of the hazard, followed by ingestion of soil (16%). TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure, while vanadium and thallium are the primary contributors associated with soil exposures.

#### **5.6.2.7 Subsurface Soil (Hot Spot RIMW-6) and Groundwater**

##### ***Future Industrial Worker***

The total estimated cancer risk for future industrial workers ( $9 \times 10^{-3}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. PCE, 1,2-DCA, and TCE are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater does not significantly impact overall risk, it should be noted that when this medium is assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, and VC as primary contributors.

The total HI for future industrial workers (62) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the hazard. TCE, cis-1,2-DCE, PCE, and toluene are the primary contributors to risk associated with groundwater exposure.

##### ***Future Excavation Worker***

The total estimated cancer risk for future excavation workers ( $8 \times 10^{-7}$ ) is below EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to inhalation of fugitive dust and vapors from soil (62%), ingestion of surface soil (22%), and inhalation of ambient air from shallow groundwater (15%).

The total HI for future excavation workers (0.1) is below EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to inhalation of ambient air from shallow groundwater (36%), ingestion of soil (33%), and inhalation of fugitive dust and vapors from soil (29%).

##### ***Future Residents***

The total estimated cancer risk for future residents ( $3 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was

conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. TCE, 1,2-DCA, PCE, VC, and benzene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure risk is within EPA's target risk range, with TCE, VC, and PCE as the primary contributors.

The total HI for future residents (395) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the hazard. TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure.

#### **5.6.2.8 Subsurface Soil (Hot Spot RISB-12) and Groundwater**

##### ***Future Industrial Worker***

The total estimated cancer risk for future industrial workers ( $9 \times 10^{-3}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. PCE, 1,2-DCA, and TCE are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater does not significantly impact overall risk, it should be noted that when this medium is assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, and VC as primary contributors.

The total HI for future industrial workers (63) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE, cis-1,2-DCE, PCE, and toluene are the primary contributors to risk associated with groundwater exposure.

##### ***Future Excavation Worker***

The total estimated cancer risk for future excavation workers ( $3 \times 10^{-7}$ ) is below EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to ingestion of surface soil (37%), inhalation of ambient air from shallow groundwater (33%), and inhalation of fugitive dust and vapors from soil (28%).

The total HI for future excavation workers (3) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to ingestion of soil (81%) and inhalation of fugitive dust and vapors from soil (10%). Thallium is the primary contributor to soil exposure hazards.

#### ***Future Residents***

The total estimated cancer risk for future residents ( $3 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the risk. TCE, 1,2-DCA, PCE, VC, and benzene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure risk is within EPA's target risk range, with benzene, arsenic and TCE as the primary contributors.

The total HI for future residents (412) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 48% of the hazard. TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall risk, it should be noted that when this medium is assessed individually, soil exposure hazard exceeds EPA's noncancer threshold, with thallium, vanadium, iron, and xylenes as the primary contributors.

### **5.6.2.9 Subsurface Soil (Hot Spot RISB-18) and Groundwater**

#### ***Future Industrial Worker***

The total estimated cancer risk for future industrial workers ( $9 \times 10^{-3}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. PCE, 1,2-DCA, and TCE are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater does not significantly impact overall risk, it should be noted that when this medium is assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, and VC as primary contributors.



The total HI for future industrial workers (62) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE, cis-1,2-DCE, PCE, and toluene are the primary contributors to risk associated with groundwater exposure.

#### ***Future Excavation Worker***

The total estimated cancer risk for future excavation workers ( $4 \times 10^{-7}$ ) is below EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to inhalation of fugitive dust and vapors from soil (47%), inhalation of ambient air from shallow groundwater (28%), and ingestion of surface soil (24%).

The total HI for future excavation workers (1) meets EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to ingestion of soil (89%).

#### ***Future Residents***

The total estimated cancer risk for future residents ( $3 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 50% of the risk. TCE, 1,2-DCA, PCE, VC, and benzene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure risk is within EPA's target risk range, with 1,2-DCA, TCE, and arsenic as the primary contributors.

The total HI for future residents (401) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall risk, it should be noted that when this medium is assessed individually, soil exposure hazard exceeds EPA's noncancer threshold, with thallium as the primary contributor.

#### 5.6.2.10 Subsurface Soil (Hot Spot RISB-25) and Groundwater

##### *Future Industrial Worker*

The total estimated cancer risk for future industrial workers ( $9 \times 10^{-3}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. PCE, 1,2-DCA, and TCE are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure risk is within EPA's target risk range, with 1,2-DCA, TCE, and arsenic as the primary contributors.

The total HI for future industrial workers (62) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE, cis-1,2-DCE, PCE, and toluene are the primary contributors to risk associated with groundwater exposure.

##### *Future Excavation Worker*

The total estimated cancer risk for future excavation workers ( $2 \times 10^{-6}$ ) is within EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to inhalation of fugitive dust and vapors from soil (70%) and ingestion of surface soil (22%). 1,2-DCA is the primary contributor to risk associated with soil.

The total HI for future excavation workers (2) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to ingestion of soil (88%). Thallium is the primary contributor to hazard associated with soil.

##### *Future Residents*

The total estimated cancer risk for future residents ( $3 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the risk. TCE, 1,2-DCA, PCE, VC, and benzene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure

risk is within EPA's target risk range, with 1,2-DCA, arsenic, TCE, and chloroform as the primary contributors.

The total HI for future residents (402) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall risk, it should be noted that when this medium is assessed individually, soil exposure hazard exceeds EPA's noncancer threshold, with thallium, as the primary contributor.

#### **5.6.2.11 Subsurface Soil (Hot Spot RISB-64) and Groundwater**

##### ***Future Industrial Worker***

The total estimated cancer risk for future industrial workers ( $1 \times 10^{-2}$ ) exceeds EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 46% of the risk. PCE, 1,2-DCA, and TCE are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure risk is within EPA's target risk range, with TCE, PCE, and 1,2-DCA as the primary contributors.

The total HI for future industrial workers (63) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE, cis-1,2-DCE, PCE, and toluene are the primary contributors to risk associated with groundwater exposure.

##### ***Future Excavation Worker***

The total estimated cancer risk for future excavation workers ( $3 \times 10^{-5}$ ) is within EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to inhalation of fugitive dust and vapors from soil (81%) and ingestion of surface soil (18%). TCE and PCE are the primary contributors to risk associated with soil.

The total HI for future excavation workers (2) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to ingestion of soil (66%) and

inhalation of fugitive dust and vapors from soil (28%). TCE is the primary contributor to hazard associated with soil.

#### ***Future Residents***

The total estimated cancer risk for future residents ( $4 \times 10^{-2}$ ) exceeds the *de maximus* of EPA's target cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . The cancer risk is predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 47% of the risk. TCE, 1,2-DCA, PCE, VC, and benzene are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, inhalation of volatiles in indoor air from shallow groundwater and soil exposures do not significantly impact overall risk, it should be noted that when these media are assessed individually, inhalation of volatiles in indoor air from shallow groundwater exceeds the risk range, with TCE, 1,2-DCA, PCE, VC, and benzene as primary contributors; and soil exposure risk also exceeds EPA's target risk range, with TCE, PCE, 1,2-DCA, VC, benzene, and chloroform as the primary contributors.

The total HI for future residents (405) exceeds EPA's noncancer threshold of 1. Noncancer health hazards are predominately due to potable uses of groundwater. Since dermal contact with potable water was conservatively estimated to be equivalent to the calculated risk for ingestion of all groundwater, each of these pathways contributed 49% of the hazard. TCE, cis-1,2-DCE, PCE, toluene, VC, xylenes, benzene, ethylbenzene, and manganese are the primary contributors to risk associated with groundwater exposure. Although, relatively speaking, soil exposures do not significantly impact overall risk, it should be noted that when this medium is assessed individually, soil exposure hazard exceeds EPA's noncancer threshold, with TCE as the primary contributor.

### **5.6.3 Final COCs**

The results of the HHRA risk characterization were used to identify the final COCs for the site. In accordance with Region 4 guidance, COCs are those COPCs that either exceed a  $1 \times 10^{-4}$  cumulative cancer risk or exceed a noncarcinogenic hazard quotient of unity. A summary of COCs by exposure medium and receptor are presented below.

#### **Surface Soil Data Sets**

##### ***Surface Soil Excluding Hot Spots (no soil beneath buildings)***

- Current O&M Worker – none selected
- Current Trespasser – none selected

##### ***Surface Soil Hot Spot 1***

- Current O&M Worker – none selected
- Future Industrial Worker – none selected
- Future Resident - **thallium**

- Current/Future Child Trespasser/Recreational User – **thallium**

***Surface Soil Hot Spot 2***

- Current O&M Worker – none selected
- Future Industrial Worker – none selected
- Future Resident - none selected
- Current/Future Child Trespasser/Recreational User - none selected

***Surface Soil Hot Spot 3***

- Future Industrial Worker – none selected
- Future Resident – **iron, manganese, thallium**
- Current/Future Child Trespasser/Recreational User - **thallium**

**Subsurface Soil Data Sets**

***Subsurface Soil Excluding Hot Spots***

- Future Industrial Worker – **vanadium**
- Future Excavation Worker – **vanadium, thallium**
- Future Resident – **vanadium, thallium**

***Subsurface Soil Hot Spot RIMW-6***

- Future Industrial Worker – none selected
- Future Excavation Worker – none selected
- Future Resident – none selected

***Subsurface Soil Hot Spot RISB-12***

- Future Industrial Worker – none selected
- Future Excavation Worker – **thallium**
- Future Resident – **thallium, vanadium**

***Subsurface Soil Hot Spot RISB-18***

- Future Industrial Worker – none selected
- Future Excavation Worker – none selected
- Future Resident – **thallium**

***Subsurface Soil Hot Spot RISB-25***

- Future Industrial Worker – none selected
- Future Excavation Worker – none selected
- Future Resident – **1,2-DCA, thallium**

***Subsurface Soil Hot Spot RISB-64***

- Future Industrial Worker – **TCE**
- Future Excavation Worker – **TCE**

- Future Resident – PCE, TCE

### **Groundwater Data Sets**

#### ***All Groundwater – Shallow and Bedrock***

- Future Industrial Worker – 1,2-DCA, cis-1,2-DCE, PCE, TCE, VC
- Future Resident – 1,2-DCA, cis-1,2-DCE, benzene, chloroethane, ethylbenzene, isopropylbenzene, manganese, methylene chloride, PCE, TCE, toluene, VC, xylenes

#### ***Shallow Groundwater***

- Current O&M Worker – none selected
- Future Industrial Worker – TCE
- Future Resident – TCE

In accordance with EPA Region 4 guidance, in addition to those chemicals that exceed calculated risk levels, any chemicals that exceed applicable or relevant and appropriate requirements (ARARs) are also considered COCs. Any COPC in groundwater that exceeds state or federal MCLs is considered a COC. Per SCDHEC guidance, chemicals that exceed EPA Region 9 Soil Screening Levels (SSLs) are considered COCs. **Table 5-7** presents the final COC list based on these criteria.

Of the VOCs in groundwater that exceed MCLs, six (1,1,1-TCA, 1,1,2-TCA, 1,1-DCE, 1,2,4-TCB, carbon tetrachloride, and 1,2-DCB) were not previously identified as COCs based on calculated risks. Of the chemicals in soil that exceed SSLs, 19 (all but 1,2-DCA, PCE, and TCE) were not previously identified as COCs based on calculated risks.

## **5.7 Uncertainty Assessment**

Uncertainties can arise from several sources in a human health risk assessment including data collection and interpretation, assumptions used to characterize exposures, and toxicity values. To compensate for uncertainty surrounding input variables, conservative assumptions are often made that tend to overestimate rather than underestimate risk. In cases where data are limited, assumptions may be based on professional judgment or subjective estimates that may under or over estimate risks.

### **5.7.1 Types of Uncertainty**

Three primary sources of uncertainty include:

- scenario uncertainty;
- parameter uncertainty; and
- model uncertainty.

Scenario uncertainty results from missing or incomplete information needed to fully define exposure and dose. This uncertainty may include errors or gaps in site characterization, professional judgment, assumptions regarding exposed populations, and steady-state conditions. Sources of parameter uncertainty include measurement and sampling errors, inherent variability in environmental and exposure-related parameters, and the use of generic surrogate data or default assumptions when site-specific data are not available. Parameter uncertainty often leads to model uncertainty. One source of modeling uncertainty is relationship errors, such as errors in correlations among chemical properties or limitations in mathematical expressions used to define environmental processes. Errors due to the use of mathematical or conceptual models as simplified representations of reality are also sources of modeling uncertainty.

Analysis of uncertainties is often divided in "true uncertainty" and "variability." The former is uncertainty due to lack of knowledge of data. Variability is uncertainty due to irresolvable variation in physical, chemical, and biological process, human behavioral patterns, seasonal changes, and data for site characterization. An example of uncertainty in this HHRA involves selection of an exposure frequency for recreational site users. No site-specific information is available and this parameter is based on professional judgment.

These three types of uncertainty have been identified in each of the four parts of this risk assessment: data evaluation, toxicity assessment, exposure assessment, and risk characterization. Uncertainty within each of these components is discussed below.

### **5.7.2 Data Evaluation**

Uncertainty is present in the data before it is even evaluated for risk assessment. This includes potential sampling bias, errors in laboratory extraction and analysis, and the protocol employed to assess contaminants identified as "nondetect." A higher level of confidence is placed on the analytical results. Sampling errors and biases and assumptions for use of nondetect data are almost always more important from uncertainty considerations.

### **5.7.3 Dose-Response Assessment**

The dose-response section involves estimating the toxicological effects of a compound on humans usually based upon laboratory animal studies. A potentially substantial source of uncertainty occurs when dose-response relationships in humans are derived from animal to human extrapolation. These associations often result from high-dose to low-dose extrapolations as well. Health effects criteria are derived with margins of safety relative to the degree of uncertainty in the value.

Another source of uncertainty in the risk assessment is the absence of toxicity criteria for certain chemical constituents. Without numerical toxicity criteria, potential noncancer hazard and/or cancer risk cannot be quantified for a given constituent.

#### 5.7.4 Exposure Assessment

The exposure assessment step involves many assumptions about "typical people" and "typical exposure scenarios" to arrive at an average daily dose. For example, a body weight of 70 kg is used for adult residents. Body weight varies for each individual, so these assumptions likely overestimate or underestimate the true dose that people are likely to receive.

Many exposure factors are chosen to err on the side of protectiveness for human health. Exposure duration, frequency, and time are set at reasonable maximum exposure values. They likely overestimate the exposures that typically occur.

The computation of the EPC for chemicals in a number of media may have resulted in an overestimate or underestimate of risks and hazards. Averages of site data exposure point concentrations may underestimate risks and hazards for some receptors while use of the maximums from site data exposure point concentration may overestimate risks and hazards for some receptors. Risks and hazards from both types of EPCs are provided in this assessment to try to bracket potential site-related impacts.

Uncertainty also exists in the use of toxicity criteria based on oral exposures to assess the risk/hazard associated with dermal exposures. In absence of a thorough understanding of the proportional difference in absorption for oral versus dermal exposures for each COPC, the dermal absorption factor inherent to the dermal exposure equation was used to account for dermal absorption of each COPC.

#### 5.7.5 Risk Characterization

Assumptions are made using best professional judgment and the scientific literature on site risk assessments. In general, assumptions made throughout this risk assessment are conservative in that they tend to overestimate exposure and resultant risk rather than underestimate it. The overall risk to public health attributable to the site is an upper-bound probability of adverse health effects. True health effects may be lower. However, it should be noted that the individual errors from different sources might be propagated into larger errors by mathematical manipulation in the risk assessment.

### 5.8 Summary and Conclusions

The risk calculations indicate that site-related environmental contamination posing potential cancer risks and noncancer hazard are related to contaminated groundwater, surface soil, and subsurface soils. The pathways of principal concern are exposure to chlorinated VOCs in groundwater through drinking water ingestion, and inhalation of VOCs in indoor air originating from groundwater. COCs in soil based on calculated risk levels are primarily the metals thallium and vanadium, with chlorinated VOCs limited to subsurface soils in hot spot locations RISB-25 and RISB-64. Nineteen additional chemicals were identified as COCs in soil based on SSL exceedances. Sixteen VOCs along with manganese were identified as COCs in



groundwater based on calculated risks as well as a comparison to drinking water standards.

# Section 6

## Conclusions

### 6.1 Summary of Findings and Conclusions

#### 6.1.1 Hydrogeology

The hydrogeologic conditions of the PSC site and resulting contaminant migration and fate characteristics are controlled by four dominant hydrogeologic features. These features are summarized below and conclusions are provided for each feature with regard to contaminant migration/fate and implications to the future FS.

##### **Saprolite**

This zone includes all identified potential source areas. As a result, the vadose zone of the saprolite is important to contaminant loading to groundwater in addition to direct contact exposures. In western portions of the site, the water table does not reside in saprolite and the vadose zone extends into the underlying PWR. Based on the MPE tests performed in the western portion of the site, the FS will be required to consider technologies applicable to lower permeability materials for these vadose zone conditions.

VOCs occur in groundwater and in the vadose zone, and extraction well performance in this zone exhibits a relatively small area of groundwater capture. Based on visual observation, well performance tests, and monitor well purging, the saprolite zone is relatively low in transmissivity. Groundwater migrating in the saprolite flows toward Wildcat Creek where it is intercepted by the more permeable stream alluvium. Ultimately, this groundwater discharges to Wildcat Creek from the alluvium. Otherwise, groundwater in the saprolite provides localized recharge to the underlying PWR and bedrock zones.

##### **Alluvium**

Source areas were not identified in the alluvium with the exception of the fuel oil area. Because the alluvium is more permeable than the saprolite, and likely more permeable than the PWR and bedrock, this feature exerts a high degree of control over the site hydrogeology. In general, groundwater migrates into the alluvium from saprolite, PWR, and bedrock from the west portion of the site. Once in the alluvium, the contaminant concentrations are diluted by the higher flux of groundwater through the alluvium as compared to the adjacent zones. Groundwater in the alluvium ultimately discharges to Wildcat Creek. However, contaminants may spread throughout the alluvium while migrating in the downstream direction before actually discharging to Wildcat Creek.

Based on the water table surface and bedrock surface mapping, and the results of the aquifer performance testing, it is probable that a significant volume of the groundwater being collected by the existing extraction wells may be derived from the alluvium and Wildcat Creek.

## **Partially Weathered Rock**

The configuration of the PWR zone is highly variable, as indicated in the cross sections presented in Section 4. The hydraulic testing also indicates that the transmissivity of the PWR is highly variable. This is to be expected as the degree of fracturing of the parent rock and nature of the weathered by products of the rock is highly variable. The PWR and regolith represent a common hydrogeologic zone with groundwater migrating within each unimpeded, but at different rates. Groundwater in PWR not migrating into the alluvium at the site will recharge the bedrock. This appears to be the case in the western portions of the site.

## **Bedrock**

Groundwater occurrence and migration in the bedrock is controlled by fractures. Small-scale fractures occurred at many investigation locations while very little fracturing was evident at others. The location of RIMW-22 provides an exception to relatively low fracture density at the site. The relatively thick sequence of PWR and frequent fracturing in the bedrock indicate that this location could supply a large quantity of groundwater to an extraction well as compared to the existing extraction wells that produce about 3 gallons per minute. The lateral extent of this fracture zone was not determined in detail during the RI, but if the fracture zone represents a linear feature across the site, it may allow an opportunity to gain a high degree of hydraulic control. Three wells (RIMW-20, RIMW-21, and RIMW-30) in the vicinity of RIMW-22 also revealed significant fracturing and weathering.

The potentiometric surface mapped for bedrock and observation well responses during the APTs indicate the possibility for two preferential flow zones in the bedrock. One of these flow zones exists in the vicinity of EW-2 and extends northeast into the alluvial deposits at RIPZ-3. A second may also exist in a nearly parallel orientation to the north in the vicinity south of RIMW-22 and leading into the alluvium toward MW-121B. However, the evidence for this feature is not as compelling because the APT results did not provide information in this area. Interceding between these two possible preferential flow zones are several bedrock monitor wells that exhibit very low transmissive conditions (as observed during development and purging). In any case, groundwater in the bedrock horizon migrates into the alluvium deposits and subsequently discharges to Wildcat Creek. However, some bedrock groundwater also appears to migrate underneath Wildcat Creek, as evidenced by the concentrations detected in bedrock well MW-121B across the creek.

## **6.1.2 Environmental Media Sampling Results**

The RI sampling results revealed that VOCs were the compounds most prevalently detected above regulatory screening criteria in soil and groundwater at the site. Three classes of VOCs and their typical degradation products were identified as having the highest concentrations in both soil and groundwater site wide: BTEX, chlorinated ethenes/ethanes, and chlorinated benzenes.

## Soil Sampling Results

Surface soil sampling results revealed concentrations exceed the EPA Region 9 PRGs for industrial soil and/or EPA Region 9 SSLs for all three of the VOC classes identified above. The highest concentrations of these compounds were primarily confined to four areas of the site: North Drum Storage Area, Solvent Ditch Area, Incinerator/Drum Repackaging Area, and South Drum Storage Area. Within these areas, the Incinerator Area had the highest concentrations of all three classes of compounds. The South Drum Storage Area had the lowest average concentrations in surface soil.

Subsurface soil sampling results revealed that concentrations also exceed industrial soil PRGs and/or SSLs in the subsurface of the four identified areas. The detected concentrations were generally higher than surface soil in all four areas, and in some cases, exceeded surface soil detections by ten times. Subsurface samples also contained detections of the three VOC classes below the water table in each area.

The presence of several VOCs above SSLs in each soil focus area indicates that ongoing sources of groundwater contamination may exist in these areas. These potential sources are likely isolated to portions of each area. The potential sources and their extent will be evaluated further in the FS.

## Groundwater Sampling Results

The groundwater sampling results for the RI are consistent with the observed soil sampling results. In the areas with the highest concentrations of VOCs in soil, groundwater concentrations were comparably high. Two additional areas of concern exist for groundwater: the former Burn Pit Area and the Fuel Oil Area. Soil concentrations may not be as high in these areas because soil excavation was previously performed in the burn pit area and because the fuel oil product is in the subsurface. The fuel oil product is associated with a former underground leak, meaning that the oil did not have to migrate through a large depth of soil to reach the groundwater.

Regolith groundwater concentrations are highest in the Solvent Area for BTEX and chlorinated ethenes and ethanes. Concentrations are above EPA MCLs throughout a large part of the site from the warehouse to Wildcat Creek, although no constituents were detected in regolith groundwater on the other side of the creek. Chlorinated benzenes are highest in the Incinerator Area, and this plume is not as large as that for the other two VOC classes.

Bedrock groundwater concentrations for BTEX and chlorinated benzenes are highest in the Solvent Ditch area, but the plume size is smaller than in regolith. The chlorinated ethene and ethane concentrations are also highest in the Solvent Ditch area, but concentrations are also high in the Burn Pit area. Chlorinated ethene/ethane concentrations appear from the west boundary of the site to Wildcat Creek, and concentrations were detected above MCLs in one well across the creek.

Groundwater concentrations are likely to be from the primary areas of concern identified for soil, and it is believed that there are plumes originating from the Solvent Ditch area, Drum Management Area, Incinerator Area, North Drum Storage Area (although co-mingled with the Solvent Ditch area), Burn Pit Area, and Fuel Oil Area. The only soil area of concern that does not correspond to higher concentrations in groundwater is the South Drum Storage Area.

### **Sediment and Surface Soil (Across Wildcat Creek) Sampling Results**

Sediment sample results from Wildcat Creek and Fishing Creek, and surface soil sample results from across Wildcat Creek, revealed that although some compounds were detected above laboratory quantitation limits, the results were either below regulatory criteria or were consistent with concentrations detected in the background samples. In addition, compounds detected were not consistent with compounds identified to be constituents of concern in the industrial portion of the PSC site.

### **6.1.3 Hydraulic Analysis Results**

The results from the hydraulic analysis indicate that the radius of influence for extraction is less than 200 feet in bedrock at EW-3 but is greater than 200 feet in PWR at EW-2. In the southern extraction well (EW-2), there appears to be good communication between the regolith and bedrock zones. The northern extraction well (EW-3) appears to have direct hydraulic communication with the regolith also, even though it is screened in bedrock.

Sustainable pumping rates for the extraction wells are fairly low, at around 3 gallons per minute for both the bedrock and PWR wells. Based on potentiometric surface maps, the extraction wells do not appear to have significant impact on the overall potentiometric surfaces of either regolith or bedrock.

### **6.1.4 Human Health Risk Assessment**

The risk calculations indicate that site-related environmental contamination posing potential cancer risks and noncancer hazard are related to contaminated groundwater, surface soil, and subsurface soils. The pathways of principal concern are exposure to chlorinated VOCs in groundwater through drinking water ingestion, and inhalation of VOCs in indoor air originating from groundwater. The final COCs in soil related to potential human exposure risks are primarily metals (thallium and vanadium), with chlorinated VOCs limited to subsurface soils in hot spot locations RISB-25 and RISB-64. However, 19 additional chemicals were identified as COCs for soil based on SSL exceedances. These compounds are present in soil at concentrations that could act as an ongoing source of groundwater contamination. Sixteen VOCs along with manganese were identified as COCs in groundwater based on calculated risks as well as a comparison to drinking water standards.

## 6.2 Recommendations for Further Action

The results from the RI will be used to develop remedial alternatives for surface soil, subsurface soil, and groundwater in the FS. Details regarding the evaluation of remedial alternatives based on the RI results will be presented in the FS.

## Section 7

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The Remedial Investigation Report is contained in four large 3-ring binders. The remainder of this Remedial Investigation Report is available through the Department's Freedom of Information Office at:

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